PERMANENT EROSION AND SEDIMENT CONTROL DESIGN GUIDELINES

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Montana Department of Transportation

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APPENDICES

LIST OF ACRONYMS

AGR	Alignment and Grade Review
BMP	Best Management Practice
BOD	Biochemical Oxygen Demand
CalTrans	California Department of Transportation
CWB	Constructed Wetland Basin
DNRC	Department of Natural Resources and Conservation
ECM	Erosion Control Mats
EPM	Engineering Project Manager
HDPE	High Density Polyethylene
MDEQ	Montana Department of Environmental Quality
MDT	Montana Department of Transportation
MS4	Municipal Separate Storm Sewer System
NRCS	Natural Resource Conservation Service
PESC	Permanent Erosion and Sediment Control
PFR	Preliminary Field Review
PIH	Plan-in-Hand
SWMP	Storm Water Management Program
TMDL	Total Maximum Daily Load
TRM	Turf Reinforcement Mats
USBR	US Bureau of Reclamation
USDA	US Department of Agriculture
WQV	Water Quality Volume

SECTION 1.0: INTRODUCTION

The purpose of these Permanent Erosion and Sediment Control Design Guidelines is to describe procedures and methods to address the following:

1. Long-term erosion that could potentially result from highway construction.

2. Sedimentation resulting from highway-related storm water runoff.

These guidelines include procedures for evaluating the need for permanent erosion and sediment control (PESC) measures during the project development process and determining which PESC measures can practicably be incorporated into the design. The guidelines also provide design details that address specific erosion and sediment control issues and discussions of construction issues and maintenance considerations.

The primary objective of this guidance document is to provide adequate information for the selection of the appropriate PESC measures to be included in the plans package. Those PESC measures would be intended to reduce soil erosion and sediment deposition into adjacent waterways and to protect the highway facility. It is anticipated that including PESC measures in the plans will clarify the Montana Department of Transportation's (MDT's) expectations of contractors, reduce maintenance needs, improve control efficiency, facilitate efficient permitting and reduce long-term control costs.

Inclusion of PESC measures into project plans should be evaluated on a project-by-project, site-specific basis. Inclusion of PESC measures into the project plans should be coupled with proactive management of basic design considerations such as limiting the area exposed to construction, maximizing use of existing and proposed vegetative cover, minimizing sliver cuts and fills, weighing appropriateness of flat-bottomed ditches as opposed to v-ditches, and using natural topographic features to the best advantage. Proactive steps could reduce the need for PESC design measures.

Erosion is uncontrolled soil movement caused by wind or water action. The byproduct of erosion, sediment, is soil particles being transported away from their natural location by wind and water action. Erosion control measures are used to stabilize disturbed or highly erosive soils. Sediment control measures are used to trap and contain, and potentially treat, sediment caused by the erosion process.

SECTION 2.0: EVALUATION AND DESIGN PROCESS

2.1 General

Incorporation of PESC measures should be considered with projects disturbing 1 acre or more, or projects having the potential to adversely affect water quality. Incorporation of PESC measures will typically be limited to projects with scopes related to rehabilitation or reconstruction and locations in proximity to sensitive resources such as impaired waterways or high quality aquatic habitat and spawning areas. PESC measures can also provide solutions for areas with a history of erosion or sedimentation problems. The PESC evaluation process will begin at the Preliminary Field Review (PFR), continue through coordination with resource agencies in permitting actions, and should be completed at the Plan-in-Hand (PIH) Review.

Site-specific factors must be taken into consideration early in the design and evaluation process. As a result, site-specific information should be gathered as early as possible in the design process.

2.2 Preliminary Field Review

For rehabilitation and reconstruction projects, the following location information can be obtained at, or prior to, the PFR:

A. General
- Soil characteristics,
- Vegetative cover,
- Topography near roadway, and
- Climate and typical weather conditions.

B. Sediment Control
- Locations of any waterways near the project,
- Presence of impaired waterways adjacent to the project (see the Montana Department of Environmental Quality [MDEQ] web site for information on impaired waterways; as of the date of this printing, the impaired waterways information was available at http://www.deq.mt.gov/wqinfo/TMDL/index.asp),
- Stream and river crossings, and
- Areas of heavy sanding.

C. Permanent Erosion Control – the following areas should be identified on the as-built plans and/or reviewed in the field:
- Cut-to-fill transitions,
- Cutslopes,
- Fill slopes steeper than 3:1,
- Ditches with long grades in cut (>1500 ft or 460 m),
- Steep embankment slopes behind guardrail,
- Bridge ends,

- Intercepting drainages in back slope,
- Existing culverts, and
- Evidence of existing erosion.

D. When possible the following information associated with erosion and sediment control should also be discussed at the PFR.
   - What potential measures can be used?
   - Will additional soils or geotechnical information be needed?
   - Will an additional, or more detailed, field survey be required? (This information is most critical for rehabilitation projects where the amount of field survey is typically limited.)
   - Will right-of-way or construction permits be necessary?

A discussion of the above information should be included in the PFR report. The road designer will coordinate with the district hydraulics engineer and the Environmental Services Bureau to determine the appropriate treatment for various types of erosion.

2.3 Alignment and Grade Review

When a project involves modifications to the roadway alignment, the majority of the site-specific information discussed in Section 2.2 may not be available until the Alignment and Grade Review (AGR) stage of design. Additionally, for projects with or without modifications to the alignment, considerably more information is available at the AGR than the PFR. That additional information, especially cross-sections and major drainage structures, will allow more detailed identification and evaluation of sites that would benefit from PESC measures and sites where design could be optimized for issues such as elimination of sliver cuts and fills.

At the AGR stage of development, sufficient information is provided to make preliminary recommendations of site-specific measures. Maintenance access to the PESC measures can also be assessed at this time. If an on-site review will not be held for the project, designers should request that Environmental Services Bureau personnel review the project to determine the appropriateness or need for sediment and/or erosion control measures.

2.4 Plan-in-Hand

A complete set of plans that includes the various PESC measures should be distributed for the PIH review. Since all of the information concerning PESC measures should be available and the plans package should be essentially complete at this stage of project development, the most in-depth review should occur at this time. The following information contained in the PIH plans should be evaluated and reviewed in the field:

A. **Assess Locations of Measures.** Are the appropriate measures shown at the correct locations? The reviewer should compare what is shown in the plans to the recommendations that were previously provided to the designer and evaluate whether additional PESC measures are needed. This task will involve a review of the plan and profile sheets, cross-sections and summaries.

B. **Assess Constructability.** Can the measures be constructed within the normal contractor operation? The reviewer should evaluate whether the sequence of work for the construction of the measures will have to be specified or if specialized equipment will be needed.

C. **Special Provisions.** Do the special provisions adequately describe the work, materials, equipment, and process required to construct the measures?

D. **Accessibility.** Is adequate access provided to the PESC measures that will require long-term maintenance? PESC measures should be designed and constructed to allow maintenance personnel to access these measures for long-term maintenance activities. Maintenance personnel will likely use heavy equipment such as skid steers, backhoes, and loaders to perform ongoing maintenance activities of these PESC measures, particularly sediment control measures. It is essential that these PESC measures are accessible.

E. **Minor Drainage.** The plans should be reviewed for the elimination of drainage culverts and the concentration of flows to new locations. The existing drainage patterns should be maintained by replacing culverts as close as possible to the existing culverts or at least within the same drainage basin. In cases where the existing culverts cannot be replaced, the design should include provisions to handle the increased flows downstream at the roadway and approach crossings and to properly reduce the energy and erosion potential at the outlet. Additionally, adequate PESC measures should be shown on the plans at cut-to-fill transitions, where drainages intercept back slopes, on long ditch grades, and along guardrail sections. (See Section A11.0: Maintenance of Existing Drainage for additional information.)

G. **Avoidance.** Avoidance of ground disturbance should be considered throughout all phases of the design process. Preservation of ground in stable, vegetated condition lessens the amount of ground exposed to erosional forces. Protection of ground on the perimeter of the project area reduces run-on from adjacent lands and surface flow through unprotected soils.

Avoidance has additional benefits in reducing right-of-way needs, utility relocations, clearing/grubbing costs, reclamation costs and long-term noxious weed control.

Simple measures such as limiting backslope grading to 3:1 or steeper slope angles, constructing V-ditches to reduce sliver cuts and establishing strict construction limits, all provide immediate and long-term benefits.

H. **Slope Rounding.** Slope rounding (not to be confused with contour grading) is a grading technique at the tops and sides of cuts and transitions to facilitate plant establishment and minimize soil erosion. Rounding of cutslopes also is an important element in achieving operational, environmental and visual functions. While engineered slopes define grades to meet engineering requirements, slope rounding should be designed so that the constructed slope blends smoothly into the surrounding landscape. Use on cut or fill slopes and transitions prior to the application of temporary soil stabilization or permanent seeding. Some limitations can include potential increase in design and construction costs, and increased right-of-way requirements.

2.5 Final Plan Review

The final plan review is an opportunity to review the completed plans. This review should be a relatively minor activity unless substantial changes were made to the PESC measures at the PIH. Coordinate with the Environmental Services Bureau to ensure permit conditions are incorporated appropriately into the plans.

SECTION 3.0: CONSTRUCTION

An appropriately developed and detailed plan will help the contractor understand MDT's expectations in regard to the work required and will assist the Engineering Project Manager in assuring that erosion and sediment control is adequately provided.

The complexity of the plans and the types, locations and quantities of various erosion and sediment control measures will be dependent upon the scale and scope of the project and the natural and man-made resources requiring protection.

The special provisions, plan sheets, and/or appropriate tables must contain adequate details for construction and inspection of the PESC measure, and should include any or all of the following:

- Specific locations, sizes and lengths of each required erosion and sediment control measure;
- Material, dimensional, and installation details for erosion and sediment control practices and facilities;
- Timing or scheduling necessary for appropriate installation, especially when a measure is intended for both temporary control during construction and permanent control following construction;
- Site preparation requirements, such as grading, compaction, or subgrade needs; and
- Details of alternatives for sites where alternative measures are considered practical.

Items or requirements specific to a given PESC measure will be included in the contract documents for the identified measure.

SECTION 4.0: MAINTENANCE

The long-term costs of operating and maintaining a PESC measure will depend on a number of factors such as frequency and duration of maintenance, equipment/materials utilized, and off-site disposal costs. The designer should evaluate these long-term costs before selecting a specific PESC measure. Regular maintenance of PESC measures is necessary to keep them functioning properly. If PESC measures are not maintained on a regular basis, they may become sources of pollutants. For example, the failure of a settling basin during a large rainfall event could discharge a measurable amount of sediment downstream. Therefore, it is important to develop and implement a schedule for monitoring and maintaining these PESC measures.

Maintenance activities may include cleaning, repairing, and replacing PESC measures, reseeding areas with poor vegetative cover, and controlling noxious weeds. Maintenance frequency will be related to the type of PESC measure and site-specific conditions such as soil type, highway slope, cut/fill slopes, storm intensity/duration and traction sand application rates. MDT Maintenance personnel will be responsible for conducting the majority of the maintenance for these measures.

A detailed description of each PESC measure and, if available, associated maintenance activities, frequency and cost are included in Appendix A.

SECTION 5.0: ADDITIONAL CONSIDERATIONS

5.1 Small Municipal Separate Storm Sewer System (MS4)

The process of evaluating projects for PESC measures as discussed in this manual can help MDT meet some of the requirements of a new permit known as the Small Municipal Separate Storm Sewer System (MS4) permit. See the MDEQ web site for information on the MS4 permit; as of the date of this printing, the MS4 permit information was available at http://deq.mt.gov/wqinfo//MPDES/StormWater/ms4.asp.

In January 2005, MDEQ instituted the MS4 permit which is required for urban areas within the state of Montana that have storm sewer systems that serve a population of at least 10,000 people. Areas currently required to have an MS4 permit are **Billings, Missoula, Great Falls, Butte, Helena, Kalispell, and Bozeman**. Cities, counties, universities, military bases, and MDT are some of the entities required to obtain permits within those areas. Under the MS4 requirements, a permit holder must regulate the discharge of potential pollutants in storm water runoff within the storm sewer system.

Each permit holder must develop, implement, and enforce a Storm Water Management Program (SWMP). Several entities are working together within each of the urban areas to undertake the program. The SWMP must address six "minimum control measures," one of which is post-construction storm water management in new development and redevelopment. In other words, the PESC process is a designated element of the SWMP. As a result, coordination and tracking is needed to demonstrate permit compliance.

Designers working in one of the seven urban areas listed above will contact the respective District Erosion Control and Construction Permitting Engineer to determine required information.

5.2 Total Maximum Daily Load (TMDL)

Section 303(d) of the federal Clean Water Act (and related regulations) requires states to assess the condition of their waters to determine where water quality is impaired (does not fully meet standards) or threatened (is likely to violate standards in the near future). The result of this review is the **303(d) List**, which must be submitted to the U.S. Environmental Protection Agency (EPA) every two years. Section 303(d) also requires states to prioritize and target water bodies on their list for development of water quality improvement strategies for impaired and threatened waters.

MDEQ is required to develop Total Maximum Daily Loads (TMDLs) for all water bodies on the 303(d) list. A TMDL is the total amount of a pollutant that a water body may receive from all sources without exceeding water quality standards. A TMDL can also be defined as a reduction in pollutant loading that results in meeting water quality standards.

Appropriate PESC measures should be considered in the early development stages of projects adjacent to listed impaired streams. MDEQ maintains the list of impaired waterways. As of the date of printing, the impaired waterways information was available at the following website: http://www.deq.mt.gov/wqinfo/TMDL/index.asp.

APPENDIX A: PERMANENT EROSION AND SEDIMENT CONTROL MEASURES

This appendix provides design information for permanent erosion and sediment control (PESC) measures. The following information is included in each detail and should be evaluated to select appropriate measures for the given situation.

1. Definition and Purpose
2. Appropriate Applications
3. Limitations
4. Design Considerations
5. Materials
6. Construction Considerations
7. Operation and Maintenance
8. Initial Cost and Cost per Year
9. Method of Payment

The decision matrix on the following pages is provided to assist in the selection of appropriate measures.

Guidelines for Minor Drainage and Erosion Control

Roadway Feature	Application	Criteria	Reference	Comments
Cut-to-Fill Transitions	Embankment Protector	1:1 max. slope	603-28 (18" min. pipe)	Use outlet protection. Hydraulically design for roadway length >1500'.
	Concrete Slope Drain	1.5:1 max. slope	613.18	Same as above.
	Riprap Slope Drain (Class II min.)	3:1 max. slope	613.18 (modified)	Same as above.
	TRM Slope Drain	4:1 max. slope	613.18 (modified)	Same as above.
Intercepting Drainages in Back Slope	Embankment Protector	1:1 max. slope	603-28 (18" min. pipe)	Use outlet protection. Hydraulically design for drainage areas >10 acres.
	Concrete Slope Drain	1.5:1 max. slope	613.18	Same as above.
	Riprap Slope Drain	3:1 max. slope	613.18 (modified)	Same as above.
	TRM Slope Drain	4:1 max. slope	613.18 (modified)	Same as above.
	Interceptor Ditch			Use applicable lining material based on the slope.
Steep Fill or Cutslopes	Cutslope Stabilization	2:1 or steeper	See Fact Sheet	Coordinate w/MDT Reclamation Specialist
	Terraced Slopes	Non-vegetated slopes	See Fact Sheet	
	Erosion Control Mat (ECM)		208-12A	
	Turf Reinforcement Mat (TRM)	Slopes with limited growth potential	208-12A	
Steep Embankment Stopes Behind Guardrail	Vegetative Growth w/ECM	Slopes that have reasonable growth potential	208-12A	Coordinate w/MDT Reclamation Specialist
	Embankment Protector w/Channelizing Curb		603-28 / 609-05	Use embankment protector or drainage chute as necessary at the end of the curb.
	Leave Curbing in Place When Replacing Guardrail	When existing slope is not well vegetated and shows signs of erosion	609-05	Plan-in-Hand team to evaluate if curbing should be removed.
Long or Steep Ditch Grades	Scraper Dips	Slopes 0.5% - 4%	208-48	Easy way to slow water and promote vegetation (see fact sheet).
	Check Dams	Slopes 1% - 7%	208-36	See fact sheet for selection
	Lined Ditch	Slopes >2%	713.12.8	Use applicable lining material based on the slope – see fact sheet.
	Ditch Block and Culvert to Divert Flows	-	203-20	Use to maintain existing drainage patterns.

Roadway Feature	Application	Criteria	Reference	Comments
Elimination of Existing Culverts	Maintain Existing Drainage	-	-	If at all possible, maintain existing drainage patterns.
	Install New Culverts Near Original Location	-	-	Replace as near as possible to the same location to maintain existing drainage patterns.
	Transfer Flows to the Nearest Downstream Culvert	-	-	Size culvert appro-privately, check ditch erosion, and apply outlet protection as necessary. Evaluate the impact of sending additional water on to a new landowner.
High Velocities at Culvert Outlets	Outlet Protection and Velocity Dissipation Devices – Energy Dissipaters	> 10 fps (3 mps)	-	Hydraulics Section provides recommenda-tions for culverts with velocities >10 fps at 10 yr. Hydraulically designed.
	Flow spreading options	> 10 fps (3 mps)	See fact sheet	Requires hydraulic design
Direct Discharge to TMDL Streams [303(d)]	Vegetated Buffer	Slopes <20:1	-	Requires hydraulic design.
	Preserve Existing Vegetation	-	-	
	Infiltration Basins	-	-	
	Constructed Wetlands	-	-	
	Settling Basin	-	-	
Erosion Along Stream Banks near Bridge Crossings or Roadway Embankments	Bioengineered Stream Bank Stabilization	Evaluate applica-tion on a case-by-case basis.	See fact sheet	Requires hydraulic design.
	Riprap Bank Protection		613-16	
	Turf Reinforcement Mat (TRM)		208-12A	
	Seeding and Planting		208-12A	
Bridge Ends	Divert Flows Before the Bridge End	-	-	Diverted flows should flow through a vegeta-tion strip before entering a stream.
	Ditch Block and Embankment Protector	Evaluate need on a case-by-case basis	603-28	Provide outlet protection and vegetation strip before flows enter a stream.
	Sediment Trap	TMDL stream	208-34	Requires hydraulic design

Roadway Feature	Application	Criteria	Reference	Comments
Sanding Material Collection on Mountain Passes	Ditch Blocks / Gravel Filter Berms	Evaluate on a case-by-case basis, based on right-of-way and maintenance access.	203-20	Requires hydraulic design.
	Channelizing Curbs		609-05	
	Sediment Trap		208-34	
	Settling Basins		-	
	Vegetated Buffer Strips		208-26	
Large Paved Parking Areas at Rest Stops or Weigh Stations	Porous Pavement	Evaluate on a case-by-case basis.	-	Requires hydraulic design.
	Settling Basin		-	
	Constructed Wetland		-	
	Infiltration Basin		-	
	Oil/Grease Separator		-	

A1.0: DITCH BLOCKS

A1.1 Definition and Purpose

A ditch block is a berm placed across a natural or man-made channel or drainage ditch to divert flows into a cross drain.

A1.2 Appropriate Applications

Ditch blocks are typically installed in the following locations:

- In roadside ditches in cut sections to divert water from the ditch to a cross drain that accesses a natural drainage.
- In roadside ditches in cut sections to divert water from the ditch to a cross drain that discharges to the roadside ditch on the other side of the roadway. When used in this case the ditch block essentially acts as a check structure to reduce the volume and velocity of flow in the ditch. It should only be used where the flow in the receiving ditch is substantially less than the flow in the contributing ditch.
- Near a cross drain in a natural drainage to ensure that the flow does not overtop the drainage divide.
- At the toe of a fill section to enhance the effectiveness of a cross drain (uncommon).

A1.3 Limitations

Severe erosion may result when a ditch block fails by overtopping.

A1.4 Design Guidelines and Considerations

- Ditch blocks should have sufficient height to divert all of the designed flow to the cross drain. The height should be a minimum of one foot below the finished roadway shoulder and preferably no higher than the top of the subgrade.
- The cross slopes of the ditch block should be no steeper than 6:1 and 10:1 slopes are desirable when the ditch block is adjacent to a high speed facility (45 mph, 70 kph).
- See MDT Detailed Drawing 203-20 for ditch block details.
- The ditch block height and the capacity of the cross drain need to coincide to ensure that runoff is not forced onto the roadway.
- Erosion protection (ECM, riprap, etc.) may be necessary on the upstream bank particularly for sites that experience higher flows and velocities. Riprap may be needed on the downstream bank if overtopping is anticipated for more frequent storm events or if the failure of the ditch block will result in damage to property or adverse environmental impacts.
- An approach may be used as a ditch block when installed in conjunction with a cross drain. The approach landing must be a 3% downgrade when used in this application.

- The Hydraulics Section may provide the design requirements for ditch blocks in unique situations, such as high flows and velocities, or where overtopping of the roadway is a concern. The details provided may include ditch block spacing, height requirements and emergency spillways.

A1.5 Materials

Standard grading item (unclassified excavation, embankment-in-place).

A1.6 Construction Considerations

Ordinary placement and compaction in accordance with standard specifications.

A1.7 Operation and Maintenance

- Inspect ditch blocks annually and after each major storm event. Repair damage as necessary.
- If a ditch block is a chronic maintenance problem, contact district engineering staff. A designed solution may be needed.

A1.8 Initial Cost and Cost Per Year

Initial Cost:	Low
Cost per Year:	Low

A1.9 Method of Payment

Included in additional excavation or roadway quantities.

A2.0: CHECK DAMS

A2.1 Definition and Purpose

Check dams are structures (generally porous) placed across a natural or man-made channel, swale, or drainage ditch that work to reduce scour and channel erosion by reducing the velocity of concentrated storm water flows to non-erosive flow velocities and by encouraging sediment dropout. A series of check dams functions as a large sediment filter that gradually improves water quality as the sediment load is removed from the runoff. Check dams are generally considered temporary sediment control; however, check dams are designed for long-term functionality.

Check dam options include:

- Option 1 - Gravel/Rock Berm
- Option 2 - Manufactured Berm
- Option 3 - Vegetated Earth Berm
- Option 4 - Scraper Dips (Dugout Ditch Basin)
- Option 5 - Fiber Roll Berm
- Option 6 - Sandbag Berm

A2.2 Appropriate Applications/Selection Criteria

- Check dam options 1 through 3 are recommended for use with all steeper channel grades (4-7%) and ditches with long grades in cuts greater than 1500 ft (460 m). Check dam options 4 through 6 may be used in conjunction with these options.
- Check dam options 4 through 6 are recommended for use with smaller channel grades (1-4%) and can be effective when used with check dam options 1 through 3 on steeper grades.
- When using check dams in combination, always consider the specific site conditions (channel grade, soil conditions, drainage area, precipitation, etc.) and project experiences, and give consideration to the effects and reach of the impounded water and sediment.
- Check dam options 5 and 6 may be used as check dams if approved by the Engineering Project Manager (EPM), and in combination with other check dams, depending on the channel grade and site conditions.
- Table A2-1 provides a selection matrix based on appropriate applications for check dams.

Table A2-1: Check Dam Selection Matrix

	Gravel Berm	Manufactured Berm	Vegetated Earth	Scraper Dips	Fiber Roll	Sandbag Berm
Small open channels with drainage areas of 10 acres (4 ha) or less	X	X	X	X	X	X
Steep channels (grades) where storm water runoff velocities exceed 5 ft/s (1.5 m/s)						
1-7%	X	X	X			
1-4%	X	X	X	X	X	X
Ditches with long grades in cuts greater than 1500 ft (approximately 460 m)	X	X	X			
During establishment of vegetation in drainage ditches or channels	X	X	X	X	X	X
Sanding material collection systems	X					

A2.3 Limitations

- Use only in small open channels which drain 10 acres (4 ha) or less.
- Do not use in continuous flow streams.
- Do not use in already vegetated areas unless erosion is expected, as installation may damage vegetation.
- Promotes sediment trapping which can be re-suspended during subsequent storms or removal of the check dam; therefore, requires maintenance following high velocity flows and may require repair.
- Do not construct using straw bales or silt fence.
- May be difficult to seed around.

A2.4 Design Guidelines and Considerations

A2.4.1 General

- Utilize erosion control blanket or geotextile in conjunction with any of the check dams. An erosion control blanket must be used with manufactured check dams, vegetated earth berms, fiber rolls and sand bags to maximize the check dam performance. Erosion control blankets prevent undermining of the check dams and encourage the earliest vegetative growth. Geotextile will enhance the performance of rock and gravel check dams. Additionally, completely line channels that are at a 7% slope or greater.
- Install the first check dam approximately 15 ft (5 m) from the outfall device and at regular intervals based on slope gradient and soil type.

- As a general rule, the maximum spacing between dams should be such that the toe of the upstream dam is at the same elevation as the top of the downstream dam. Based on this criteria alone, recommended spacing for a 2 ft (0.6 m) high check dam given various channel slopes is as follows:

  1%-3%: place check dams at approximately 300 ft (90 m) spacing
  3%-4%: place check dams at approximately 200 ft (60 m) spacing
  > 4%: place check dams at approximately 100 ft (30 m) spacing

  Check dam spacing may be adjusted on a project-by-project basis by the Engineering Project Manager.
- The maximum approach face of the check dam slope within the clear zone is 6:1 or flatter.
- Locate a spillway at the center of the check dam. The spillway must be at least 6 inches (150 mm) lower than the outer edges of the dam.
- Key check dams into the sides and bottom of the channel a minimum of 4 inches (100 mm) or to manufacturers' specifications.

A2.4.2 Gravel/Rock Berm

- Standard gravel check dams are 2 ft (0.6 m) high with 2:1 side slopes and a spillway at the center of the dam at least 6 inches (150 mm) lower than the outer edges of the check dams.
- The maximum height of the check dam at the center should not exceed 2 ft (0.6 m). The check dam needs to be wide enough to reach from bank to bank of the ditch or swale.
- Rock berms must be located outside the clear zone.

A2.4.3 Manufactured Berm

- Channels should be constructed with linear sections that will allow complete contact between the manufactured check dam and the channel bottom (fit flatly). Failure to have complete contact can result in the device bridging the soil, resulting in concentrated erosion routes and leading to failure of the device.
- Manufactured check dams used in V-shaped channels will be installed to the manufacturers' specifications.
- Consider the properties of UV-stable high density polyethylene (HDPE) manufactured check dams versus biodegradable HDPE manufactured check dams.
- Failures occur due to excessive check dam spacing. The following equation is used to determine the check dam spacing:

  $$\text{Maximum check dam spacing} = \frac{\text{height of manufactured check dam}}{\text{channel slope}}$$

A2.4.4 Vegetated Earth Berm

Standard vegetated earth berms will have a minimum height of 2 ft (0.6 m), side slopes of 2:1 or flatter, a spillway at the center of the berm at least 6 inches (150 mm) lower than the outer edges of the berm, and a minimum base width of 4.5 ft (1.4 m). These dimensions may be modified at the discretion of the Engineering Project Manager based on site-specific conditions, such as soil conditions and/or precipitation.

A2.4.5 Scraper Dips (Dugout Ditch Basin)

- Refer to Detailed Drawing 208-48 for design guidelines and considerations.
- Dugout ditch basins can remain in place and be seeded during the permanent seeding of the ditch.

A2.4.6 Fiber Roll Berm

Refer to Detailed Drawing 208-38 for design guidelines and considerations for Fiber Roll Berms.

A2.4.7 Sandbag Berm

Refer to Detailed Drawing 208-42 for design guidelines and considerations for Sandbag Berms.

A2.5 Materials

A2.5.1 Gravel Berm

Check dams constructed from gravel must be 100% passing the 2 inch (50 mm) screen and 10% maximum passing the No. 4 sieve (4.75 mm). Dam material may be pit-run or crushed aggregate.

A2.5.2 Manufactured Berm

Manufactured berms are available in biodegradable and non-biodegradable high density polyethylene (HDPE).

A2.5.3 Vegetated Earth Berm

Vegetated earth berms should be constructed of compacted soil, topsoiled, and seeded.

A2.5.4 Fiber Roll Berm

Fiber rolls should be either prefabricated rolls or rolled tubes of erosion control blanket.

A2.5.5 Sandbag Berm

Refer to Detailed Drawing 208-42 for bag material and size.

A2.6 Construction Considerations

A2.6.1 Gravel Berm

- Install the gravel berm perpendicular to the direction of flow.
- Construct a spillway at the center of the dam. The spillway must be at least 6 inches (150 mm) lower than the outer edges of the dam.
- Gravel may be placed by hand or by mechanical method to achieve complete ditch or swale coverage and ensure that the center of the dam is lower than the edges.
- Space the gravel berms as indicated above. Check dam spacing may be adjusted on a project-by-project basis by the Engineering Project Manager.

A2.6.2 Manufactured Berm

- Shape the channel with linear sections. If the channel bottom is less than the width of the manufactured check dam, the panel length must be adjusted (cut) to fit flatly on the channel bottom.
- Install erosion control blanket.
- Place manufactured check dams perpendicular to direction of flow over the erosion control blanket. Overlap panels by a minimum of 2 inches (50 mm). Cut a slot in the crest of the overlapping dam to allow contact between the foot of the dam and the blanket (bottom of the channel).
- Secure manufactured check dams with pins or staples through the foot of the dam and a folded erosion control blanket as specified in the manufacturer's recommendations.

A2.6.3 Fiber Roll Berm

- Place fiber rolls at 50 ft (15 m) maximum spacing or as approved by the Engineering Project Manager (EPM).
- Dig a trench for the fiber roll.
- Install erosion control blanket through the trench prior to staking the fiber roll.
- Stake the fiber roll in the erosion control blanket-lined trench according to Detailed Drawing 208-38.

A2.6.4 Sandbag Berm

- Install sandbag berms as linear control, placing bags along a level contour.
- Upon ending the sandbag run, place the last bags to angle up the slope so that flows do not escape around the end.
- Stack sandbags to height using a pyramid approach with the upper sandbags overlapping the lower row.

- All bags placed within the clear zone require measures to protect sand from freezing. Freeze reduction methods require the EPM's approval.

A2.7 Operation and Maintenance

A2.7.1 General

- Inspect check dams after each significant storm event [0.5 inch (13 mm) in one hour], or, according to permit requirements if there is an active storm water permit.
- Remove sediment from behind the dam when it accumulates to one-third the original height.
- Remove accumulated sediment and dispose of properly, or seed accumulated sediment to stabilize, whichever is most practical for the situation.
- Inspect for erosion along the edges of the check dams and repair as required immediately.

A2.7.2 Manufactured Berms

Remove sediment after significant storm events [0.5-inch (13 mm) in one hour] to maintain the permeability and performance of the check dam.

A2.7.3 Scraper Dips (Dugout Ditch Basins)

Remove sediments and repair basins when required to maintain the functionality of the basins. Dispose of the sediment appropriately.

A2.7.4 Fiber Rolls

Repair or replace split, torn, unraveling, or slumping fiber rolls.

A2.7.5 Sandbags

Reshape or replace sandbags as needed.

A2.8 Initial Cost and Cost Per Year

Initial Cost: Moderate
Cost per Year: Low

A2.9 Method of Payment

The method of payment will depend on the material used for the check dam.

A3.0 CHANNELIZING CURBS

A3.1 Definition and Purpose

A channelizing curb is any curb that intercepts surface runoff and directs it to a specific outfall such as a slope drain or embankment protector.

A3.2 Appropriate Applications

Channelizing curbs are used to divert runoff from slopes that are susceptible to erosion, due to their steepness or lack of vegetation. Channelizing curbs have often been considered as a temporary measure until vegetation is established on a slope. However, before a curb is removed, the slope should be evaluated to ensure that the vegetation is sufficient to prevent erosion.

Channelizing curbs can also be used to divert runoff from a sensitive watercourse.

A3.3 Limitations

- Severe erosion may occur if the spacing or capacity of the outfalls is inadequate.
- On routes with posted speeds equal to or greater than 45 mph (70 km/h), channelized curb should be used in conjunction with a guardrail.
- The Hydraulics Section should evaluate the spread width of the flow contained by the curb if the embankment protector spacing exceeds the calculated spacing. A safety issue for vehicles can occur if the spread width of the flow encroaches on the travel lane.

A3.4 Design Guidelines and Considerations

- The dimensions of channelized curbs should be in accordance with Detailed Drawing 609-05 unless special conditions exist.
- Channelized curbs must be used in conjunction with other PESC BMPs.
- The primary design consideration is the spacing of the outfalls as described in detail in Section 17.2 of the Road Design Manual.
- The outfall sites must be evaluated to determine if additional erosion control measures are needed at the outfall.
- Curb materials and construction practices need to comply with MDT Standard Specifications and special project conditions.

A3.5 Materials

Plant mix or concrete.

A3.6 Construction Considerations

Construct channelized curbs in accordance with the Standard Specifications and Detailed Drawings.

A3.7 Operation and Maintenance

The maintenance of channelizing curbs is minimal unless they are damaged by vehicle or snowplow impacts. Channelized curbs should be inspected annually.

A3.8 Initial Cost and Cost Per Year

Initial Cost:	Low
Cost per Year:	Low

A3.9 Method of Payment

Channelized curbs are measured and paid by the linear foot (m) of new curb.

A4.0 CUTSLOPE STABILIZATION

A4.1 Definition and Purpose

Cutslope stabilization is the use of one or more methods to stabilize a portion of a slope that is often unaddressed. Steep slope angles, exposure of unweathered parent material (bedrock), lack of moisture infiltration capacity and difficulty in reestablishing a cover of vegetation create an environment that produces large amounts of sediment movement into roadside ditches. This sediment can move with flowing water off-site and increases maintenance costs by clogging culverts. This measure is intended to retain sediment on the slope, as opposed to trying to contain the eroded material once it reaches the ditch section.

A4.2 Appropriate Applications

For most situations, treating the lower 1/3 of the slope should act as an effective filtering zone to reduce the amount of sediment from reaching a ditch section. These measures would also serve to prevent headcutting from erosion originating near the slope toe. Use one of the following methods individually, or in combination, to stabilize the lower portion of large cutslopes.

- Large rock veneer,
- Erosion control blanket, with seeding,
- Compost blanket, with seeding,
- Topsoil treatment, with seeding.

Current MDT policy restricts topsoil replacement to slopes flatter than 2:1.

Use is restricted to large cuts where any of the above measures is cost-prohibitive to treat the entire slope.

This BMP does not eliminate the MDT standard seeding protocol for the entire slope. It is meant to supplement standard seeding by incorporating practices that either foster vegetation establishment or act as a barrier to sediment transport into the ditch.

A4.3 Limitations

Any of the methods involving seeding should only be specified on slopes capable of supporting plant growth. An assessment of whether soil conditions are capable of supporting plant growth should be made by the MDT Agronomist prior to the plan-in-hand. If the slopes in the general area from the original road construction appear likely to support plant growth, then the selection of one of the seeding treatments is a viable option.

If the slope faces exposed after grading will be composed of hard bedrock, little plant growth can be expected, as well as limited sediment generation from weathering. No treatment is necessary in such cases.

Rock veneer is appropriate in areas where the finished slope is composed of highly erodable material, but plant growth is not expected due to contributing factors such as high salt levels, excessive steepness and/or extreme clay or fine silt content.

Rock veneer may also be appropriate around exposed seepage zones where piping erodes soil particles. Seepage zones are most prevalent where a water-bearing zone lies atop a salt-rich layer of clay (shale).

With any of the treatments, a hard point in the slope must be constructed along, and parallel to, the top edge of the BMP. The hard point is necessary to prevent undercutting of the installation, whether rock or one of the seeding methods. The hard point will be constructed of a trenched-in piece of turf reinforcement mat.

A4.4 Design Considerations

The use of this BMP will be contingent upon the location and size of large cuts that are constructed at 2:1 or steeper angles. The MDT Reclamation Specialist may decide that none of the specialized treatments is necessary or practical given the size and number of cutslopes. Regardless of selected treatment, the BMP is not to extend higher than about 20 ft (6 m) up the slope from the ditch bottom elevation. It may be necessary to leave the bottom 5 ft (1.5 m) of the slope untreated if the rock veneer is used in order to eliminate a hazard in the recovery zone.

The MDT Reclamation Specialist will recommend appropriate BMP slope method(s) to be incorporated into the design once the construction limits are established and an assessment is made of the appropriateness of slope stabilization. The default treatment will always be topsoiling/erosion control blanket and seeding of the lower third of the slope [or maximum 20 ft (6 m) high].

The remaining upper portions of the slope will be seeded according to the “Area 2” instructions in the seeding special provision.

Following coordination with the MDT Reclamation Specialist, the designer will calculate the quantity of each designated method, summarize the methods by stationing and list them separately in the schedule of items for bidding purposes. A summary frame will be provided in the set of plans detailing the location and size of each of the methods.

A4.5 Materials

The materials will depend on the measure that is selected

A4.6 Construction Considerations

A4.6.1 Rock Veneer, with Seeding

Grade the treated area of the slope to a smooth, even surface. Broadcast seed (wet or dry) the area with the "Area 2" seed mixture and rates. Following seeding, install a coconut erosion control blanket meeting MDT Standard Specification 713.12.4 - Type B. Only use blankets constructed with 100% non-synthetic, biodegradable netting and stitching.

Cover the blanket with a single layer of Class I riprap, meeting MDT Standard Specification 701.06.2. Place the riprap in a manner that limits blanket ripping or dislodgement. Rocks must not be dropped from a distance greater than 1-2 ft (0.3-0.6 m) from the soil surface.

A4.6.2 Compost Blanket, with Seeding

Prepare the area to be treated by first scarifying it with a chisel plow or disk, operated parallel to the slope. Alternative methods of preparation that produce a roughened surface may be approved by the EPM. Dry broadcast seed the area with the "Area 2" seed mixture and rates. Following seeding, apply an equivalent amount of compost over the area to attain an average depth of 1 inch (25 mm). It is assumed that depths will be variable given the surface roughness. Overspray the compost with a tackifier to assure retention and performance of the compost for 6 months.

A4.6.3 Erosion Control Blanket, with Seeding

Grade the treated area of the slope to a smooth, non-compacted surface. Immediately prior to seeding, prepare the surface by dozer tracking or harrowing. Broadcast seed (wet or dry) the area with the "Area 2" seed mixture and rates. Following seeding, install a 70% straw and 30% coconut erosion control blanket meeting MDT Standard Specification 713.12.2 - Type STC. Only use blankets constructed with 100% non-synthetic, biodegradable netting and stitching.

A4.6.4 Topsoiling and Erosion Control Blanket, with Seeding

Prepare the area to be treated by first scarifying it with a chisel plow or disk, operated parallel to the slope. Following scarification, place a 2 inch (50 mm) layer of salvaged or furnished topsoil over the treated area. Broadcast seed (wet or dry) the area with the "Area 2" seed mixture and rates. Following seeding, install an erosion control blanket meeting MDT Standard Specification 713.12.2 – C. Type STC. Only use blankets constructed with 100% non-synthetic, biodegradable netting and stitching.

A4.7 Operation and Maintenance

Maintenance of the ditches is restricted to avoid damaging the slope stabilization BMPs.

A4.8 Initial Cost and Cost Per Year

Initial Cost:	Moderate
Cost per Year:	Low

A4.9 Method of Payment

The stabilization method is measured and paid by the square yard (square meter).

A5.0 SLOPE DRAINS

A5.1 Definition and Purpose

A slope drain is a measure used to intercept and direct surface runoff or groundwater into a stabilized watercourse, trapping device or stabilized area. Slope drains are often used to intercept and direct surface flow away from slope areas to protect cut or fill slopes.

A5.2 Appropriate Applications

- Slope drains are typically used on back slopes where surface runoff is concentrated due to natural or man-made features. These features may consist of minor drainages intercepted by the back slope or at the outfalls of furrow ditches constructed on the top of the back slope.
- Slope drains can be used in cut-to-fill transitions. (If the volume of runoff or the slope steepness limits the use of a slope drain in these locations, utilize embankment protectors to protect the cut-to-fill transition.)
- Slope drains can be used in conjunction with a channelized curb. The type of slope drain is usually limited to concrete chutes or pipes, due to the height of drop typically associated with channelized curbs.

A.5.3 Limitations

Severe erosion may result when slope drains fail by overtopping, piping, pipe or joint separation. Limitations to the height of drop and slope depend on the type of material used for the slope drains.

A.5.4 Design Considerations

Slope drains include concrete, riprap, geotextile-lined and turf reinforcement mat drainage chutes. The use of turf-reinforced drain chutes and riprap drain chutes are not recommended for slopes steeper than 3:1. The use of culverts for slope drains is discussed in Section A9.0 Embankment Protectors. Recommended design parameters for various slope drains are summarized below.

A5.4.1 Concrete Drain Chute

- Maximum drop = 30 ft (9 m)
- Maximum slope = 1.5:1*

*For slopes steeper than 1.5:1, a culvert is generally more cost-effective (see Section A9.0 Embankment Protectors).

A5.4.2 Riprap Drain Chute

- Maximum drop = 30 ft (9 m)
- Maximum slope = 3:1

A5.4.3 Turf Reinforcement Mat (TRM)

- Maximum drop = 20 ft (6 m)
- Maximum slope = 4:1

When using slope drains, limit drainage area to 10 acres (4 ha) per slope drain. The designer should contact the Hydraulics Section for drainage areas greater than 10 acres. Utilize outlet protection/velocity dissipation devices at the slope drain outfall. Where slope drains outfall into roadside ditches the outlet protection may have to extend up the inslope of the roadway. In areas of higher flows where slope drains are intercepting furrow ditches, consider regrading the furrow ditches and providing additional slope drains.

- Channelization on top of the slope to direct flow to the slope drain is essential. Direct surface runoff to slope drains by using furrow ditches, berms or other dikes as shown on Detailed Drawing 613-18.

- Slope drain materials, including riprap, synthetic liners, and concrete, need to comply with MDT Standard Specifications or special project conditions.

- Where an approach is installed in cut sections, the roadside ditches for the approach will act as slope drains. Therefore, the ditches should be evaluated and designed using slope drain criteria.

A5.5 Materials

Concrete, riprap or turf reinforcement mat (TRM) can be used depending on the type of slope drain selected.

A5.6 Construction Considerations

When installing slope drains:

- Install slope drains perpendicular to slope contours.
- Use geotextiles in conjunction with riprap slope drains. Input from the Geotechnical Section may be necessary.
- Compact soil around and under entrance and outlet, and along the length of the slope drain.
- Protect area around inlet with geosynthetic liner meeting MDT Standard Specifications. Protect outlet with riprap or other energy dissipation device. For

high-energy discharges, reinforce riprap with concrete or use reinforced concrete device.

A5.7 Operation and Maintenance

- Inspect after each major storm, but at least once per year.
- Inspect outlet for erosion and downstream scour. If eroded, repair damage and install additional energy dissipation measures. If downstream scour is occurring, it may be necessary to reduce flows being discharged into the channel unless other preventative measures are implemented.
- Inspect slope drainage for accumulations of debris and sediment.
- Remove built-up sediment from entrances and outlets as required. Flush drains if necessary; capture and settle out sediment from discharge.
- Make sure water is not ponding at inappropriate areas (for example, inlet of slope drain, roadside ditch, etc.).

A5.8 Initial Cost and Cost Per Year

Initial Cost:	Moderate
Cost per Year:	Low

A5.9 Method of Payment

- Concrete drain chutes are measured and paid by the cubic yard (cubic meter) of concrete. The payment includes any necessary reinforcement.
- Riprap drain chutes are measured and paid by the cubic yard (cubic meter).
- TRMs are measured and paid by the square yard (square meter).

A6.0 LINED DITCHES

A6.1 Definition and Purpose

Lined ditches are utilized to convey surface water in areas that are susceptible to erosion and discharge this surface water to a stabilized watercourse, drainage pipe, or channel. Ditches may be lined with concrete, asphalt, riprap, turf reinforcement mats (TRM), or coconut-fiber erosion control mats (ECM). Riprap-lined ditches may be grouted in place for high flow velocities and steep slopes.

Lined ditches are ideal for collecting and dispersing surface water in a controlled manner. Well-designed ditches provide an opportunity for sediments and other pollutants to be removed from runoff water before it enters surface waters or groundwater. Efficient removal of runoff from the roadway will help preserve the roadbed and banks. In addition, a stable ditch will not become an erosion problem itself.

A6.2 Appropriate Applications

Lined ditches may be utilized in the following areas/situations:

- Areas that are susceptible to erosion where vegetation is difficult to establish,
- Steep slopes/high flow velocities,
- Below steep grades where runoff begins to concentrate,
- At the top of slopes to divert run-on from adjacent or undisturbed slopes, and
- At bottom and mid-slope locations to intercept sheet flow and convey concentrated flows.

The designer may consider lining ditches with concrete, asphalt, riprap, TRM, or ECM. TRMs are composed of ultraviolet (UV) stabilized polymeric fibers, filaments, nettings and/or wire mesh, integrating to form a three-dimensional matrix ¼-¾ inch (6-19 mm) thick.

Riprap, TRM, and ECM-lined ditches should be considered before concrete and asphalt since they decrease flow velocities (thus decreasing the erosion potential). In addition, TRM and ECM promote vegetative growth. Concrete and asphalt-lined ditches may be appropriate for ditches located within the clear zone and on heavily sanded mountain passes.

A6.3 Limitations

- Lined ditches are not suitable as sediment trapping devices. Sediment-laden runoff should be discharged into a sediment trapping facility and/or treated in the ditch via check dams.
- Concrete- and asphalt-lined ditches do not provide any energy dissipation; therefore, these ditches may have considerable erosion at the outlets if they are not properly protected.

A6.4 Design Considerations

- Lined ditches should be considered for slopes steeper than 2%, flow velocities greater than 5 ft/sec (1.5 m/s), and/or areas that are susceptible to erosion and difficult to establish vegetation. Specify ECM, TRM, concrete, asphalt, or riprap for the ditch liner.
- Select the ditch liner according to the following slopes:
  - Unlined: <2%
  - Coconut-fiber ECM: 2-5%
  - TRM: 5-8%
  - Concrete and asphalt: >8%
  - Riprap/grouted riprap: >8%
- Verify that flow velocities for ECM and TRM do not exceed the manufacturers' recommendations.
- Size riprap based on slope and expected flow velocities in the ditch. Place geotextile between the riprap and the underlying soil surface to prevent soil movement into or through the riprap. Riprap may be grouted in place for high flow velocities and steep slopes.
- Limit drainage area to approximately 10 acres (4 ha) per slope drain. The designer should contact the Hydraulics Section for drainage areas greater than 10 acres. Size ditches to convey the peak flow from the 10-year, 24-hour storm event from the contributing area.
- Design and grade ditch and bank side slopes at a maximum 2H:1V ratio.
- Shape the ditch bottom so that it is trapezoidal or parabolic-shaped and at least 2 ft (0.6 m) wide and 2 ft (0.6 m) deep to help slow and disperse water.
- Provide energy dissipation measures as necessary to prevent erosion at the ditch outlet.

A6.5 Materials

The materials utilized for lining ditches include concrete, asphalt, riprap, TRM, or ECM.

A6.6 Construction Considerations

- Remove all vegetation, roots, and rocks and construct the ditch according to the design plans and specifications.

- Install the ditch liner according to the design plans and specifications. TRM and ECM will be installed according to the manufacturer's recommendations.
- Place outlet protection before—or in conjunction with—the construction of the ditch so that it is in place when the channel begins to operate.

A6.7 Operation and Maintenance

- Inspect channel linings, embankments, beds, and outlets of ditches for erosion and accumulation of debris/sediment after major storm events. Remove debris/sediment, replace lost riprap, and repair ditches, linings, and embankments as necessary.
- Regrade/reshape ditches for improving flow capacity, as necessary. Repair/replace liners immediately following grading activities.

A6.8 Initial Cost and Cost per Year

Construction and O and M costs for ditches are dependent on a number of factors such as:

- Type (concrete, asphalt, riprap, TRM, or ECM),
- Size (length, width, and depth), and
- Location (mountainous or prairie terrain).

Construction costs are low to medium and O and M costs are low.

A6.9 Method of Payment

Typically, the liner will be measured and paid by the square yard (square meter). The excavation or embankment to construct the ditch will be paid as a separate grading item.

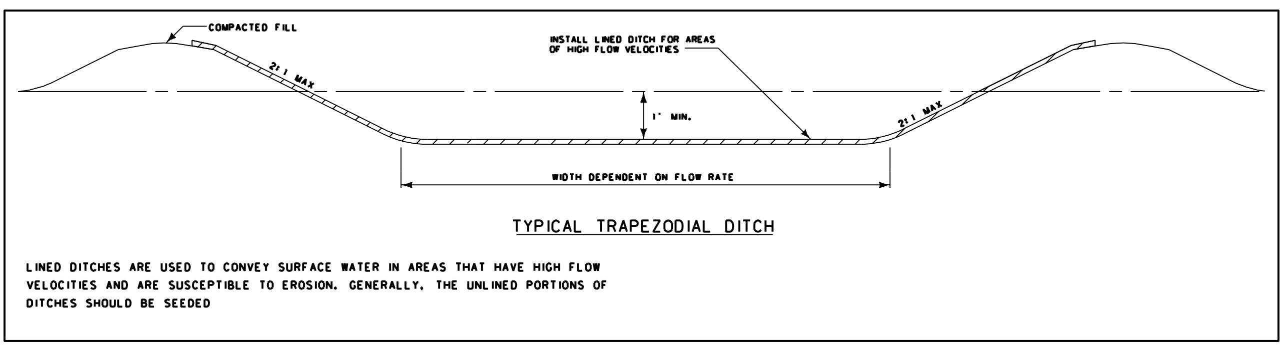


Figure A6-1: Lined Ditch

A7.0 EROSION CONTROL MATS (ECM)

A7.1 Definition and Purpose

An Erosion Control Mat (ECM) is an organic or synthetic biodegradable open weave mat or blanket. ECM is installed in channels or on slopes steeper than 3:1 to establish and reinforce vegetation and to control erosion. ECM is used in these applications rather than straw mat or another temporary erosion control measure, since ECM is more durable and will provide a longer life.

A7.2 Appropriate Applications

- ECM is used when disturbed soils may be particularly difficult to stabilize.
- ECM can be used on steep slopes (steeper than 3:1) and in channels with velocities greater than 3 ft/sec (0.9 m/s) but less than 8 ft/sec (2.4 m/s).
- ECM can be used on rocky slopes to interrupt rill formation.
- Coordinate with the MDT Reclamation Specialist to determine appropriate type of ECM for site-specific conditions that will influence the length of time needed for vegetation to become established.

A7.3 Limitations

- Do not use on channels where vegetation is already established.
- Do not use on channels with gradient greater than 5% or flow velocities greater than 8 ft/sec (2.4 m/s). [Refer to the Turf Reinforcement Mat section for areas with concentrated runoff, velocities greater than 8 ft/sec (2.4 m/s), and gradients greater than 5%.]
- On slopes over 20 ft (6 m) in length or with slopes flatter than 3:1, coordinate with MDT Reclamation Specialist to determine if site-specific conditions justify the higher cost of ECM compared to another PESC or a temporary erosion control measure, such as straw mat.
- Good surface contact is necessary for the erosion control mats to function effectively.

A7.4 Design Considerations

- Many types of ECM exist. Selection of the appropriate type of ECM will be based on site-specific conditions. (See Table A7-1 below.)
- Refer to the Cutslope Stabilization section for bottom of slope ECM application.
- Biodegradable staples may be used in areas where metal staples are undesirable (e.g., rest areas)
- In a constructed channel do not design intermittent installations of ECMs unless the channel is interrupted by another BMP.
- Provide ECM coverage of the entire wetted area.

Table A7-1: Selection of ECM

Time Needed to Establish Vegetation	Use	ECM or Blanket Type
1 - 2 seasons	Ditches with gradients 2-5%, lengths greater than 50 ft (15 m), and flow velocities less than 6.5 ft/sec (2 m/s). Slopes 2.5:1 - 3:1	Straw/coconut blanket, wood fiber mat, degradable netting on two sides, or synthetic material.
3 - 4 years	Ditches with gradients 5% or less, flow velocities less than 8 ft/sec (2.4 m/s), flow depth less than 6 inches (150 mm), and erodible soils. Slopes 2:1 - 2.5:1	Coconut fiber, netting on two sides, UV-stabilized, or synthetic material.

A7.5 Materials

The type of material used may vary. Refer to Section 713.12 of the Standard Specifications for additional information on a specific material

A7.6 Construction Considerations

- Install ECM in accordance with manufacturer's specification and MDT Standard Specification Sections 610 and 622.03.4.
- Figure A7-1 illustrates some typical ECM installation requirements.
- For channel applications, install ECM parallel to flow of water.
- For channel applications, install ECM when channel is dry.
- Direct the flow to the center of the ECM.

A7.7 Operation and Maintenance

- Re-anchor loosened matting; replace missing matting and staples as required.
- Perform inspections periodically, especially after a storm event that results in runoff.
- Execute required repairs or maintenance immediately.

A7.8 Initial Cost and Cost Per Year

Initial Cost: Moderate
Cost per Year: Low

A7.9 Method of Payment

ECMs are measured and paid by the square yard (square meter).

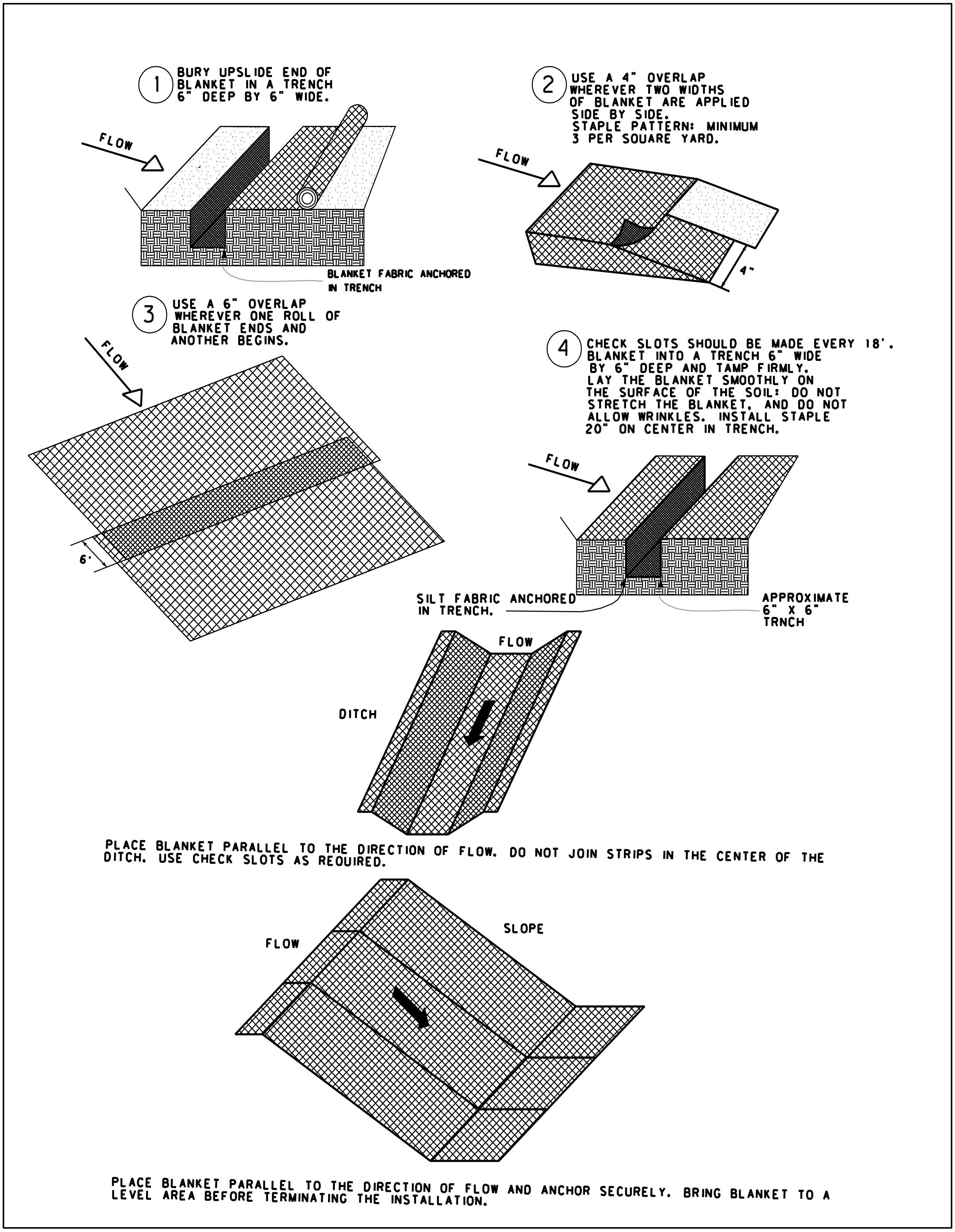
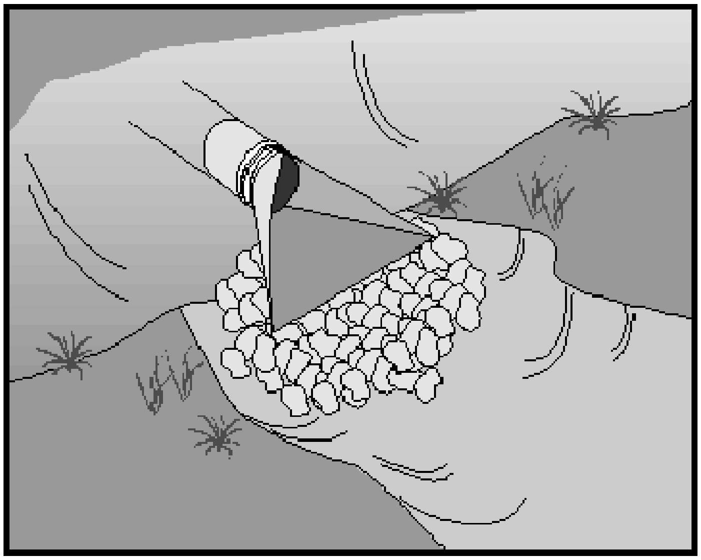


Figure A7-1: Erosion Control Blanket Installation

A8.0: OUTLET PROTECTION/VELOCITY DISSIPATION DEVICES



A8.1 Definition and Purpose

Outlet protection for culverts, storm drains, or even steep ditches and flumes is essential to preventing major erosion and damage to downstream channels and drainage structures. Outlet protection can be a channel lining or a structure or flow barrier. Outlet protection is designed to lower excessive flow velocities from pipes and culverts, prevent scour, and dissipate energy. Effective outlet protection must begin with efficient storm drainage system design that uses adequately sized pipes, culverts, ditches, and channels placed at the most efficient slopes and grades.

A8.2 Appropriate Applications

Outlet protection is needed wherever discharge velocities and energies are sufficient to erode the immediate downstream reach. These devices may be used at the following locations:

- Outlets of pipes, drains, culverts, conduits, slope drains, diversion ditches, swales, or channels.
- Outlets located at the bottom of mild to steep slopes.
- Discharge outlets that carry continuous flows of water.
- Outlets subject to short, intense flows of water, such as flash floods.
- Points where lined conveyances discharge to unlined conveyances.
- Outlets of other PESC measures including embankment protectors and drainage chutes.

A8.3 Limitations

- Riprap outlet protection can occupy a large area, which may require additional easements.
- Loose rock may be washed away during high flows.
- Grouted riprap and concrete structures may break up in areas of freeze and thaw. Weepholes and adequately drained foundations are necessary for these types of outlet protection.

- Sediment caught in the rock outlet protection device may be difficult to remove without removing the rocks.

A8.4 Design Considerations

The MDT Hydraulics Section typically designs permanent outlet protection and velocity dissipation devices for cross culverts and storm drains. Outlet protection is also required with the installation of other permanent erosion control devices including embankment protectors, slope drains, interceptor ditches and settling basin outlets.

- There are many types of energy dissipaters, with a rock apron being the most common and the one that is represented in the attached detail drawings. The Engineering Project Manager may approve other types of devices including stilling basins, impact barriers, and baffle chutes. *Coordinate with the Hydraulics Section for design of these types of outlet protection and velocity dissipation devices.*
- Rock outlet protection is effective at limiting erosion when the rock is sized and placed appropriately. Increase rock size for high velocity flows. Use sound, durable, angular rock.
- When designing the outlet project, consider flow depth, roughness, gradient, side slopes, discharge rate, and velocity. The discharge pipe size governs the rock depth and outlet protection length, using hydraulic calculations and velocities to determine the size of the device.
- For proper operation of apron:
  - Align apron with receiving stream and keep it straight throughout its length. If a curve is needed to fit site conditions, place the curve in the upper section of the apron.
  - If the apron riprap is large in size, protect underlying filter fabric with a gravel blanket.
- Outlets on slopes steeper than 10% will need additional protection.
- Where lump sum payments are used for structural devices provide quantities for information purposes.

A8.5 Materials

The type of material will depend on the measure selected (channel lining, flow barrier, structure).

A8.6 Construction Considerations

Refer to Section 613 of the Standard Specifications and the Detailed Drawings.

A8.7 Operation and Maintenance

- Inspect outlet protection on a regular basis for erosion, sedimentation, scour or undercutting.

- Repair or replace riprap, geotextile or concrete structures as necessary to handle design flows.
- Remove trash, debris, grass, sediment or burrowing animals as needed.

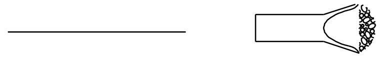
A8.8 Initial Cost and Cost Per Year

Initial Cost:	High
Cost per Year:	Low

A8.9 Method of Payment

- Cubic yards (cubic meters) for riprap.
- Lump sum for structural devices.

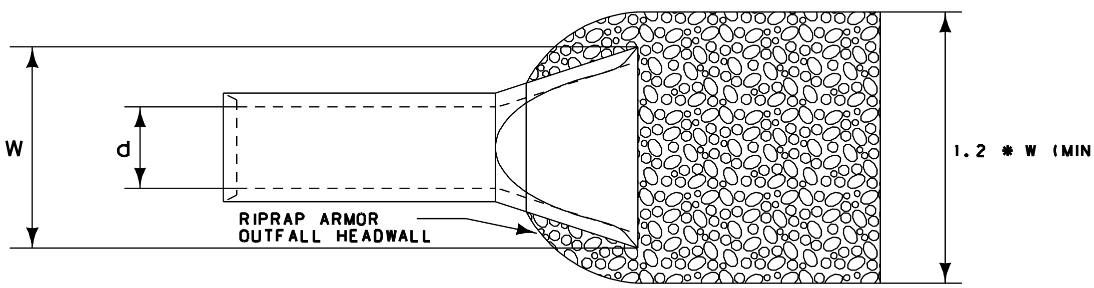
SYMBOL:



OUTLET PROTECTION/VELOCITY DEVICES SS-10:

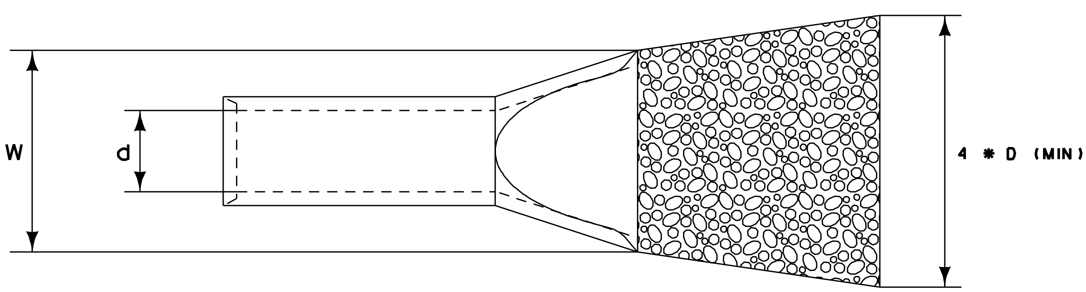
OUTLET PROTECTION AND VELOCITY DISSIPATION DEVICES ARE PLACED AT PIPE OUTLETS TO PREVENT SCOUR AND REDUCE THE VELOCITY AND/OR ENERGY OF EXISTING STORM WATER FLOWS. THESE DEVICES CAN BE USED AT THE OUTLET OF PIPES, DRAINS, CULVERTS, SLOPE DRAINS, DIVERSION DITCHES, SWALES, CONDUIT OR CHANNELS AND SHOULD BE IMPLEMENTED ON A PROJECT-TO-PROJECT BASIS WITH OTHER BMPs WHEN DETERMINED NECESSARY BY THE ENGINEER

FOLLOW GUIDELINES BELOW FOR SIZING OUTLET PROTECTION AND VELOCITY DISSIPATION DEVICES. FOLLOWING ENGINEER'S APPROVAL. OTHER MATERIALS MAY BE SUBSTITUTED FOR RIPRAP. GEOTEXTILE PLACEMENT MAY BE ELIMINATED FOLLOWING ENGINEERS APPROVAL. PLACE TYPE 1 OR TYPE 2 BANK PROTECTION AT PIPE OUTLET. FOR PIPE DIAMETERS LARGER THAN 600 mm AND/OR HIGH FLOWS. THE APPLICATION IS NOT CONSIDERED TEMPORARY AND A MONTANA REGISTERED ENGINEER'S DESIGN IS REQUIRED.



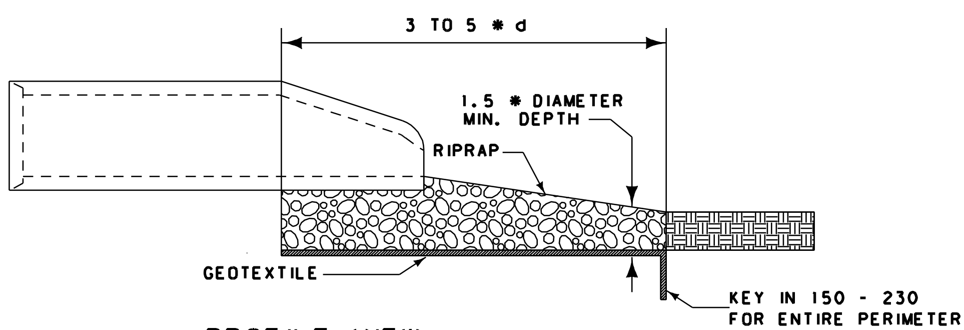
PLAN VIEW-CHANNELIZED FLOW

(OUTFALL TO CHANNEL OR DITCH)



PLAN VIEW-UNCHANNELIZED FLOW

(OUTFALL TO UNCONFINED SURFACE-OVERLAND FLOW)



PROFILE VIEW

Figure A8-1: Outlet Protection/Velocity Dissipation Devices

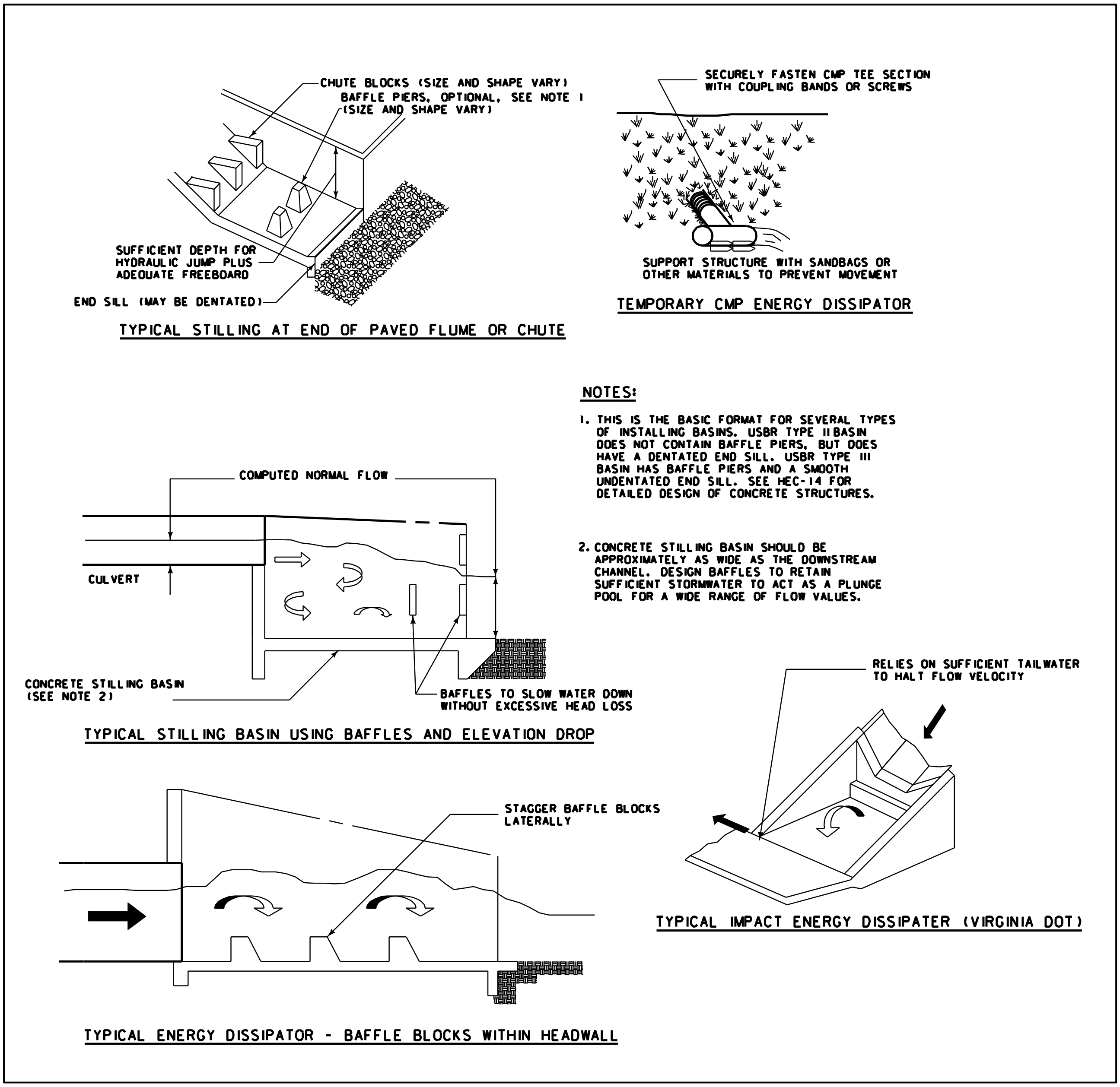


Figure A8-2: Various Energy Dissipators and Stilling Basins

A9.0 EMBANKMENT PROTECTORS

A9.1 Definition and Purpose

An embankment protector is a type of slope drain consisting of a pipe extending down a slope to a designed outfall. It is used to intercept and direct surface runoff into a stabilized watercourse, trapping device or stabilized area.

A9.2 Appropriate Applications

Embankment protectors are typically used in conjunction with channelized curbs, at bridge ends and in cut-to-fill transitions.

They can also be used on back slopes where the height of the drop, the steepness of the slope or the volume of surface runoff exceeds the capability of other types of slope drain.

The installation of embankment protectors is not necessary for bridges that have rail configurations without curbs.

A9.3 Limitations

Severe erosion may result when the inlet is overtopped or as the result of piping or pipe separation.

Where embankment protectors are used on back slopes, energy dissipation/erosion protection at the outfall in the roadside ditch should consist of some type of hard armoring. This may consist of riprap, paving a section of ditch or installing a concrete dissipater. Riprap should not be used in the roadside ditch if it is within the clear zone.

A9.4 Design Considerations

An embankment protector with channelized curb should be designed in accordance with the criteria provided in Section 17.2 of the Road Design Manual.

Where embankment protectors are used in cut-to-fill transitions, the pipe size is determined through hydraulic analysis. The designer should have the Hydraulics Section evaluate the capacity of the embankment protector if the drainage area at the cut-to-fill-transition is greater than 10 acres (4 ha). The drainage area can be determined from aerial photos, topographic maps, or a field survey.

The outfall of the embankment protector should be evaluated to determine which energy dissipation or erosion control measures are needed. A riprap apron sized according to hydraulic practice is generally sufficient.

- Securely anchor and stabilize pipe and appurtenances into soil.
- Check to ensure that pipe connections are watertight.
- Use standard flared end sections at the inlet and outlet for pipes 12 inches (300 mm) in diameter or greater.
- Embankment protector materials and construction practices need to comply with MDT Standard Specifications, MDT Detailed Drawing 603-28 and special project conditions.
- In areas of heavy sanding, provide sediment traps to collect the sanding material upstream of the embankment protector inlet.

A9.5 Materials

Embankment protectors are typically constructed with corrugated metal pipe. Optional pipe materials and coating may be considered depending on soils conditions.

A9.6 Construction Considerations

Embankment protectors should be constructed in accordance with the detailed drawings and standard specifications.

A9.7 Operation and Maintenance

- Inspect after each major storm, but at least once per year.
- Inspect outlet for erosion and downstream scour. If eroded, repair damage and install additional energy dissipation measures. If downstream scour is occurring, it may be necessary to reduce flows being discharged into the outfall area unless other preventative measures are implemented.
- Inspect embankment protector inlet for accumulations of debris and sediment.
- Inspect the embankment protector for distortion, leakage or pipe separation.
- Remove built-up sediment from entrances and outlets as required. Flush pipe if necessary; capture and settle out sediment from discharge.

A9.8 Initial Cost and Cost Per Year

Initial Cost:	Moderate
Cost per Year:	Low

A9.9 Method of Payment

Embankment protectors are paid by the linear foot (linear meter). This includes any preparatory work at the inlet. Any measures installed at the embankment protector outlet will be paid separately under the appropriate item for the specific measure.

A10.0 TERRACED SLOPES

A10.1 Definition and Purpose

Terraced slopes are made of either earthen embankments or ridge and channel systems. They reduce damage from erosion by collecting and redistributing surface runoff to stable outlets at slower speeds and by increasing the distance of overland runoff flow. They also surpass smooth slopes in holding moisture, help to minimize sediment loading of surface runoff and increase the effectiveness of temporary and permanent soil stabilization practices.

A10.2 Appropriate Applications

Terraced slopes are most suitable for non-vegetative slopes that have existing or expected water erosion problems and they are only effective when there are suitable runoff outlets provided. They are usually limited to use on long, 2:1 or steeper slopes. Terraces are used on embankments or cutslopes prior to the application of temporary soil stabilization or permanent seeding.

A10.3 Limitations

Terraced slopes are not appropriate for use on sandy, rocky or shallow soils. Sloughing could occur if too much water permeates the soil in a terrace system and cut and fill costs could increase substantially. Construction of terraced slopes is more time-consuming than construction of standard slopes.

A10.4 Design Considerations

Terraced slopes should be designed with adequate and appropriate outlets and should be installed according to a well-developed plan. Acceptable outlets include grassed waterways, vegetated areas, or tile outlets. Any outlet that is used should be able to redirect surface runoff away from the terraces and toward an area that is not susceptible to erosion or other damage.

Design considerations include:

- Consult with the MDT Geotechnical Section to identify slope or soil stability concerns and recommendations.
- Show the terracing in plan details and on the cross sections.
- Whenever possible, vegetative cover should be used in the outlet.
- The water surface design elevation of the terrace should be no lower than the water surface design elevation of the outlet when both are performing at design flow.
- Consider future maintenance requirements. Slopes steeper than 3H:1V cannot be mowed.

A10.5 Materials

No materials are required.

A10.6 Construction Considerations

- During construction of the terrace system, dust control procedures should be followed.
- Proper vegetation/stabilization practices should be followed while constructing these graded terraces.

A10.7 Operation and Maintenance

During construction, regular inspections of the terraces should occur after any major storms and during the BMP inspections to ensure that the terraces are structurally sound and have not been subject to erosion.

A10.8 Initial Cost and Cost Per Year

Initial Cost:	High
Cost per Year:	Low

A10.9 Method of Payment

The cost of terracing slopes will be included in the unit price bid for unclassified excavation.

TERRACED SLOPES SS-13:

TERRACED SLOPES ARE MADE OF EITHER EARTHEN EMBANKMENTS OR RIDGE AND CHANNEL SYSTEMS THAT ARE PROPORTIONALLY SPACED AND ARE CONSTRUCTED WITH AN ADEQUATE GRADE. TERRACES REDUCE DAMAGE FROM EROSION BY COLLECTING AND REDISTRIBUTING SURFACE RUNOFF TO STABLE OUTLETS AT SLOWER VELOCITIES AND BY INCREASING THE DISTANCE OF OVERLAND RUNOFF FLOW. THIS BMP IS USUALLY LIMITED TO USE ON LONG STEEP SLOPES WITH A WATER EROSION PROBLEM, OR WHERE IT IS ANTICIPATED THAT WATER EROSION WILL BE A PROBLEM. TERRACED SLOPES ARE NOT APPROPRIATE FOR USE ON SANDY, STONY, OR SHALLOW SOILS.

DESIGN TERRACED SLOPES WITH ADEQUATE AND APPROPRIATE OUTLETS. ENGINEER'S APPROVAL IS REQUIRED PRIOR TO MODIFICATIONS OF SPECIFIED TERRACED SLOPES.

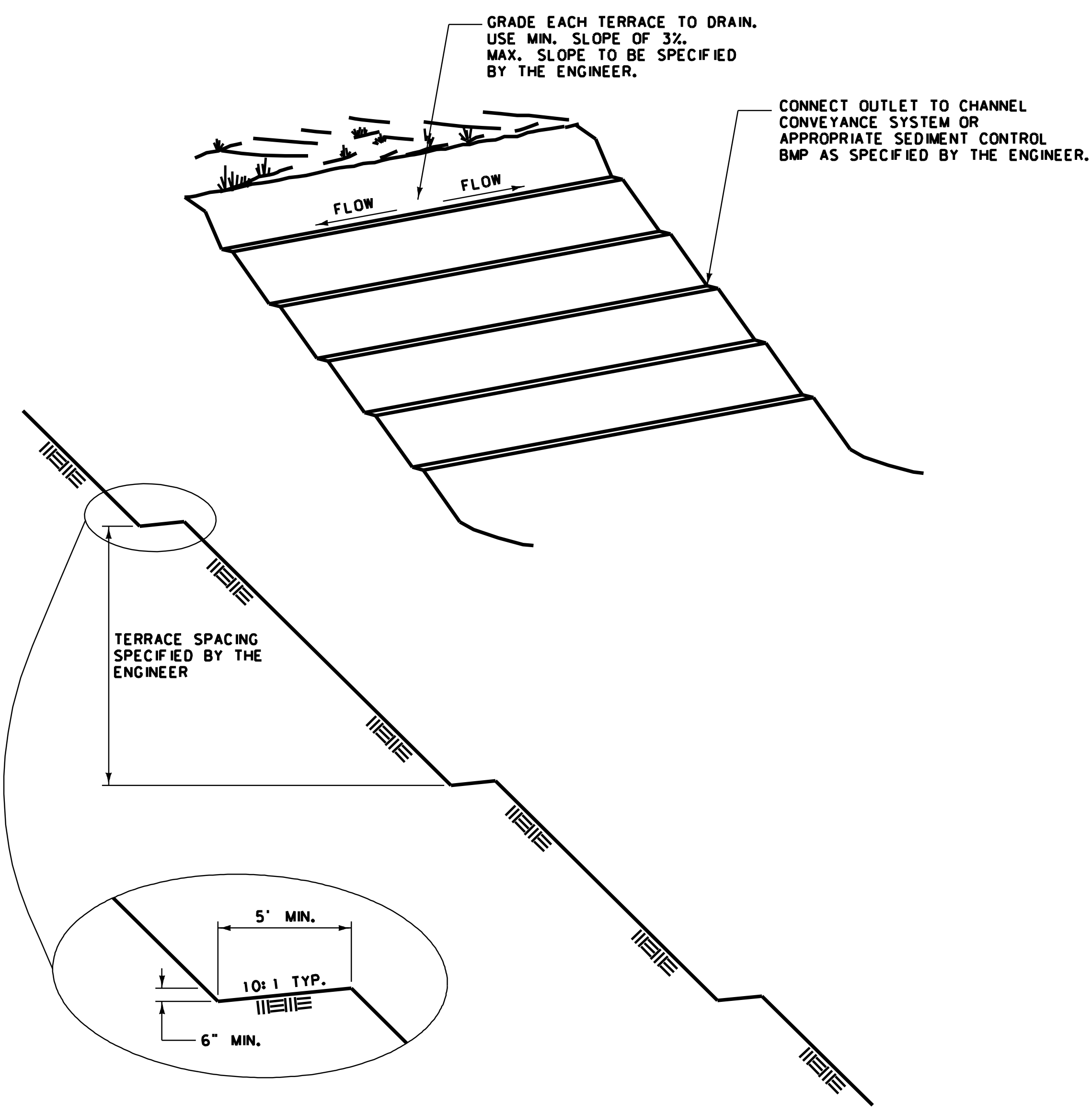


Figure A10-1: Terraced Slopes

A11.0: MAINTENANCE OF EXISTING DRAINAGE

A11.1 Definition and Purpose

The purpose of maintaining the existing drainage patterns is to ensure that a new roadway configuration does not result in concentration of runoff or obstruction of minor drainages. The failure to do so can result in water trapped next to the roadway and can potentially impact the hydrology of a drainage. Alteration in site runoff characteristics can cause an increase in the volume and frequency of runoff flows (discharge) and velocities that cause flooding, accelerated erosion, and reduced groundwater recharge, and contribute to degradation of water quality and the ecological integrity of streams.

A11.2 Appropriate Applications

Impacts to the existing drainages most often occur as the result of projects that involve changes to the horizontal or vertical alignment. The locations of minimum sized [24 inch (600 mm)] culverts are often overlooked and new grades may result in new low spots where water may be trapped.

Roadway widening may also impact roadside drainage. Many older sections of roads were constructed using side borrow which resulted in substantial roadside ditches. New wider roadway templates often fill these ditches leaving no clear drainage path.

A11.3 Limitations

Maintaining the existing drainage patterns may not always be practical, but should always be considered as part of the design process.

A11.4 Design Considerations

Whenever a project involves adjustments to the horizontal or vertical alignment or includes major widening:

- Review as-built plans and conduct on-site reviews to determine the location of minimum sized culverts.
- Perpetuate minor drainage crossings unless it is impractical to do so.
- If a crossing must be eliminated, direct the flow to the nearest natural drainage. Determine if the drainage can accommodate the additional flow.
- Since the elimination of the minor drainage crossing will often result in additional flow in the roadside ditch, evaluate the need for erosion control measures in the ditch to prevent erosion that would result from the increased flow.
- Where new grades result in new low spots where runoff would otherwise be trapped, grade the ditch to drain. This may require a ditch profile that is independent of the roadway profile.

- Where new templates fill in existing roadside ditches, drain ditches may be needed at the toe of the fill to promote positive drainage to a natural drainage course. As in cut sections, these ditches may require a ditch profile that is independent of the roadway profile.
- In cases where the flow pattern is changed from the original situation, evaluate the effects of the additional flow on the existing features such as drainages and wetlands to ensure that it does not result in adverse impacts.

A11.5 Materials

This section is not applicable.

A11.6 Construction Considerations

This section is not applicable.

A11.7 Operation and Maintenance

This section is not applicable.

A11.8 Initial Cost and Cost Per Year

This section is not applicable.

A11.9 Method of Payment

This section is not applicable.

A12.0: BIOENGINEERED STREAMBANK STABILIZATION

A12.1 Definition and Purpose

Streambank erosion is the loss of soils along streams and rivers predominantly due to the force of flowing water. The seepage of groundwater and the overland flow of surface water runoff also contribute to the erosion of streambanks. The purpose of this control measure is to protect streambanks from the erosive forces of flowing water through use of designed vegetative and/or structural measures.

Bioengineered methods integrate plant materials and landform modifications in order to stabilize slopes and streambanks. Bioengineered techniques utilize natural elements such as trees, shrubs, rocks and native vegetation to stabilize banks as opposed to manmade structures constructed of synthetic materials.

A12.2 Appropriate Applications

Biostabilization is applicable to stream channels whose banks are susceptible to erosion due to water flows, excessive runoff, groundwater seepage, ice, or debris. Biostabilization is generally applicable where flow velocities exceed 5 ft/sec (1.5 m/s) or where simple revegetation methods are inappropriate or ineffective for streambank protection. Biostabilization is desirable where riprap or other hard methods pose aesthetic concerns and in areas where erosion poses a lower risk to the transportation facility.

The control measure selected should be compatible with improvements planned or being carried out in other channel reaches. The type of vegetative cover to be used should be based on the soil type, stream velocities, adjacent land use and anticipated level of maintenance to be performed.

Refer to the individual methods outlined below for more specific applications/ information.

A12.3 Limitations

- These control measures may require special permitting from resource agencies such as the Montana Departments of Environmental Quality and Fish, Wildlife and Parks and the US Army Corps of Engineers.
- Because of the sometimes complex issues, Hydraulics and Environmental Services should be involved throughout the process.

A12.4 Design Considerations

Since each reach of channel requiring protection is unique, measures for structural streambank protection should be installed according to a plan based on specific site conditions. The Hydraulics Section will coordinate with the Environmental Services Bureau to determine the appropriate design.

Develop designs according to the following principles:

- Make protective measures compatible with other channel modifications planned or being carried out in adjacent channel reaches.
- Ensure that streambank protection extends between stabilized or controlled points along the stream.
- Do not change channel alignment without a complete evaluation of the anticipated effect on the rest of the stream channel, especially downstream.
- Give special attention to maintaining and improving habitat for fish and wildlife.
- Ensure that all requirements of state law and all permit requirements of local, state, and federal agencies are met.
- All methods listed below must be designed for structural stability and erosion resistance.

Stream channel erosion problems vary widely in type and scale and no one measure works in all cases. Where long reaches of stream channels require stabilization, make detailed stream studies.

Before selecting a structural stabilization technique, the designer should carefully evaluate the possibility of using vegetative stabilization in conjunction with structural measures to achieve the desired protection. Vegetative techniques are generally less costly and more compatible with natural stream characteristics.

A12.4.1 Brush Layering

Brush layering consists of placing live branch cuttings in small benches excavated into the base of the slope. Cuttings taken from willow species when properly installed will root and stabilize slopes. The portions of the brush that protrude from the slope face assist in retarding runoff and reducing surface erosion. Brush layering is somewhat similar to live fascine systems because both involve the cutting and placement of live branch cuttings. The two techniques differ principally in the orientation of the branches and the depth to which they are placed in the slope. In brush layering, the cuttings are oriented more or less perpendicular to the slope contour. In live fascine systems, the cuttings are oriented more or less parallel to the slope contour. The perpendicular orientation is more effective from the point of view of earth reinforcement and mass stability of the slope.

A12.4.2 Joint Planting

Joint planting (or vegetated riprap) involves tamping live cuttings of rootable plant material into soil between the joints or open spaces in rocks that have previously been placed on a slope. Alternatively, the cuttings can be tamped into place at the same time that rock is being placed on the slope face. A bedding material or penetrable fabric must be used under the rock.

A12.4.3 Live Fascines (Wattling Bundles)

Live fascines are long bundles of live branch cuttings bound together in long rows and placed in a shallow trench along the base of the bank, immediately above normal water level. Cuttings are taken from willow species. When properly installed, live stakes angled into the slope face at intervals will root and quickly begin to stabilize the slopes. The goal is for natural recruitment to follow once slopes are secured. This stabilization method has the advantage of causing relatively little site disturbance.

A12.4.4 Live Staking

Live staking is a form of soil bioengineering involving the planting of live, rootable vegetative cuttings into the ground along the streambank (also known as woody cuttings, posts, poles, or stubs). If correctly prepared and placed, the live stake will root and grow. As cuttings develop, they create a living root mat that stabilizes the soil by reinforcing and binding soil particles together and by extracting excess soil moisture. They protect streambanks from erosion, minimizing sediment and associated nutrient impacts downstream. Established cuttings also moderate bank and water temperatures, facilitate colonization of other species, and provide forage. Most willow and cottonwood species are ideal for live staking because they root rapidly. This is an appropriate technique for repair of small earth slips and slumps that are frequently wet.

A12.4.5 Stream Deflectors (aka Vanes)

Structures that limit channel width and push flow away from the bank are referred to as stream deflectors. Single-wing deflectors, the most common type, consist of a main log or placed rock angled downstream. When properly constructed, either singly or in series in low gradient meandering streams, deflectors divert base flows toward the center of the channel and, under certain conditions, increase the depth and velocity of flow thereby creating scour pools and enhancing fish habitat. Stream deflectors should be constructed in the lower half of long riffles to prevent undesired backwater effects from reaching upstream. Banks opposite these structures should be monitored for excessive erosion.

A12.4.6 Tree Revetment

In a tree revetment, uprooted, live, whole trees are cabled tightly together, laid on their sides and secured to the bases of banks along eroded stream segments, tops pointed downstream and overlapped about 30%. Anchoring is usually accomplished through a system of cables, in a shingled pattern, like the shingles on a roof. The technique is most useful when stream bank heights are at least 6 ft (1.8 m), with a steep incline; revetments cannot be constructed on gradually sloped streambanks. Species used are those with abundant, dense branching to promote sediment trapping, and those which are decay-resistant (juniper, for example). Tree revetments can greatly slow the stream current along an eroding bank, which decreases erosion and allows sediment to deposit in the revetment's tree branches. In addition to trapping sediment, the deposited materials form an excellent seedbed in which the seeds of riparian trees and other plants can sprout and grow. The resulting growth spreads roots throughout the revetment and into the streambank. Tree revetments also provide excellent habitat for birds, fish, and other wildlife.

A12.4.7 Vegetated Geogrid (Soil Wrap)

Vegetated geogrids, also known as soil wraps, are used to rebuild a bank. They are similar to the brush layering fill technique except that an erosion control fabric (geotextile) is wrapped around each soil lift. Live branch cuttings are laid between the layers.

A12.4.8 Log Spur

A log spur bank feature is constructed by partially burying the top of a large cut tree in the stream channel with the lower branches pointing into the current. The lower half of the tree lies on the bottom of the stream and is anchored by boulders along the stream bottom. Log-spur bank features are designed to stabilize the stream channel and provide in-stream habitat for aquatic organisms.

A12.5 Materials

Materials will vary depending on the specific stabilization measure used.

A12.6 Construction Considerations

Refer to the specific stabilization measures in Section 12.4 Design Considerations.

A12.7 Operation and Maintenance

Check stabilized streambank sections after spring runoff, and make any needed repairs immediately to prevent further damage.

A12.8 Initial Cost and Cost Per Year

Initial Cost: Moderate
Cost per Year: Moderate

A12.9 Method of Payment

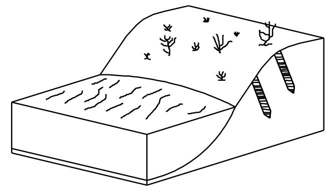
The installation of stabilization measures will be paid as a lump sum.

TABLE C-1. BIOTECHNICAL TECHNOLOGIES

(Adapted from Li and Eddleman (2002) (continued).

LIVE STAKES

LIVE, ROOTABLE WOODY CUTTING INSERTED AND TAMPED DIRECTLY INTO SOIL. ROOT SYSTEM BINDS SOIL TOGETHER. FOLIAGES HELP REDUCE FLOW ENERGY.

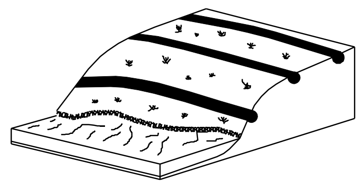


APPLICATIONS AND PROPERTIES:

- MOST EFFECTIVE WHEN USED ON SMALL, SIMPLE PROBLEM SITES.
- SUITABLE FOR STREAM/BANKS WITH GENTLE SLOPES.
- ENHANCES PERFORMANCE OF SURFACE EROSION CONTROL MATERIALS, SUCH AS ROLLED EROSION CONTROL PRODUCTS (RECPs)
- STABILIZES TRANSITIONAL AREAS BETWEEN DIFFERENT BIOTECHNICAL TECHNIQUES.
- INEXPENSIVE.

LIVE FASCINES

LIVE CUTTINGS TIED TOGETHER IN LINEAR CYLINDRICAL BUNDLES. INSTALLED IN SHALLOW TRENCHES THAT NORMALLY MATCH CONTOURS.

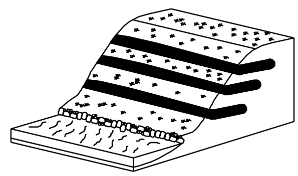


APPLICATION AND PROPERTIES:

- TERRACE AND CHECK DAM-LIKE STRUCTURES BREAK UP SLOPE LENGTH AND REDUCE SHEET FLOW VELOCITY.
- PROTECTS SLOPE FROM SHALLOW SLIDE FAILURES (1 TO 2 FEET IN DEPTH).
- EFFECTIVE ON GENTLE SLOPES (LESS THAN 33 PERCENT).
- CAUSES LITTLE SITE DISTURBANCE IF INSTALLED PROPERLY.
- OTHER TECHNIQUES SUCH AS LIVE STAKING, POST PLANTS, AND RECPs CAN BE EASILY APPLIED TOGETHER.

BRUSHLAYERING

LIVE CUTTING INSTALLED INTO STREAMBEDS BETWEEN LAYERS OF SOIL IN CRISSCROSS OR OVERLAPPINGPATTERN



APPLICATION AND PROPERTIES:

- LIVE CUTTINGS PROTRUDING BEYOND THE FACE OF THE STREAMBANK INCREASE THE HYDRAULIC ROUGHNESS, WHICH REDUCES RUNOFF VELOCITY.
- LAYERS OF LIVE CUTTINGS CAN FILTER SEDIMENT OUT OF THE SLOPE RUNOFF.
- STABILIZES SLOPES AGAINST SHALLOW SLIDING.
- CUTTING INSTALLED INSIDE THE STEAMBANKS REINFORCE SLOPES BY THE ROOT-STEM-SOIL STRUCTURE.
- PREFERRED ON FILL RATHER THAN CUT SLOPES.

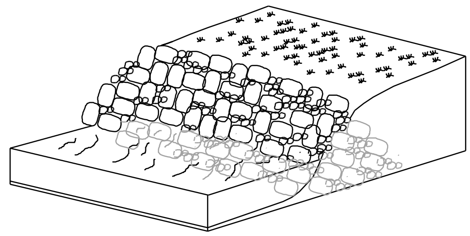
Figure A12-1:

TABLE C-1. BIOTECHNICAL TECHNOLOGIES

(Adapted from Li and Eddleman (2002) (continued).

JOINT PLANTING

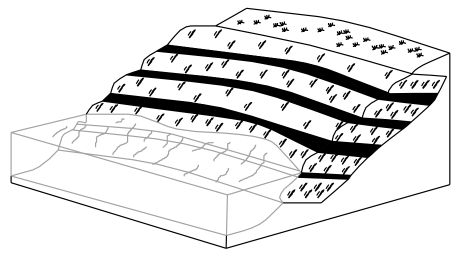
ROCK RIPRAPS WITH LIVE STAKES TAMPED INTO JOINTS OR OPENINGS BETWEEN ROCKS



APPLICATIONS AND PROPERTIES:
- ENHANCES AESTHETICS OF EXISTING ROCK RIPRAP.
- PROVIDES BETTER HABITATS THAN RIPRAP ALONE.
- IMPROVES THE STRENGTH OF RIPRAPS ALONE.
- PROVIDES IMMEDIATE PROTECTION AND IS EFFECTIVE IN REDUCING EROSION ON ACTIVELY ERODING BANKS.
- MANY AVAILIBLE DESIGN GUIDELINES BECAUSE THE RIPRAP IS WIDELY USED.

VEGETATED GEOGRIDS

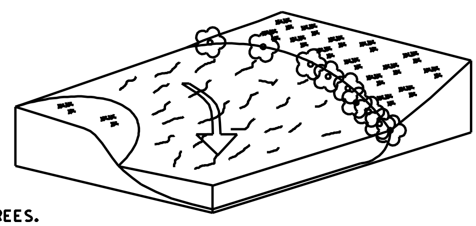
BRUSHLAYERING INCORPORATED WITH NATURAL OR SYNTHETIC GEOTEXTILES WRAPPED AROUND EACH SOIL LIFT BETWEEN THE LAYERS OF LIVE CUTTING.



APPLICATIONS AND PROPERTIES:
- HIGH STRENGTH TECHNIQUES THAT STABILIZES STEEP SLOPES UP TO 1:1.
- THE SYSTEM MUST BE BUILT DURING LOW FLOW CONDITIONS.
- LABOR INTENSIVE, CAN BE COMPLEX AND EXPENSIVE.
- USEFUL IN RESTORING OUTSIDE BENDS WHERE EROSION IS A PROBLEM.
- CAPTURES SEDIMENTS, WHICH RAPIDLY REBUILD TO FURTHER STABILIZE THE TOP OF THE STREAMBANK.
- PROVIDES IMMEDIATE STABILIZATION WITHOUT VEGETATION GROWTH.

TREE REVETMENT

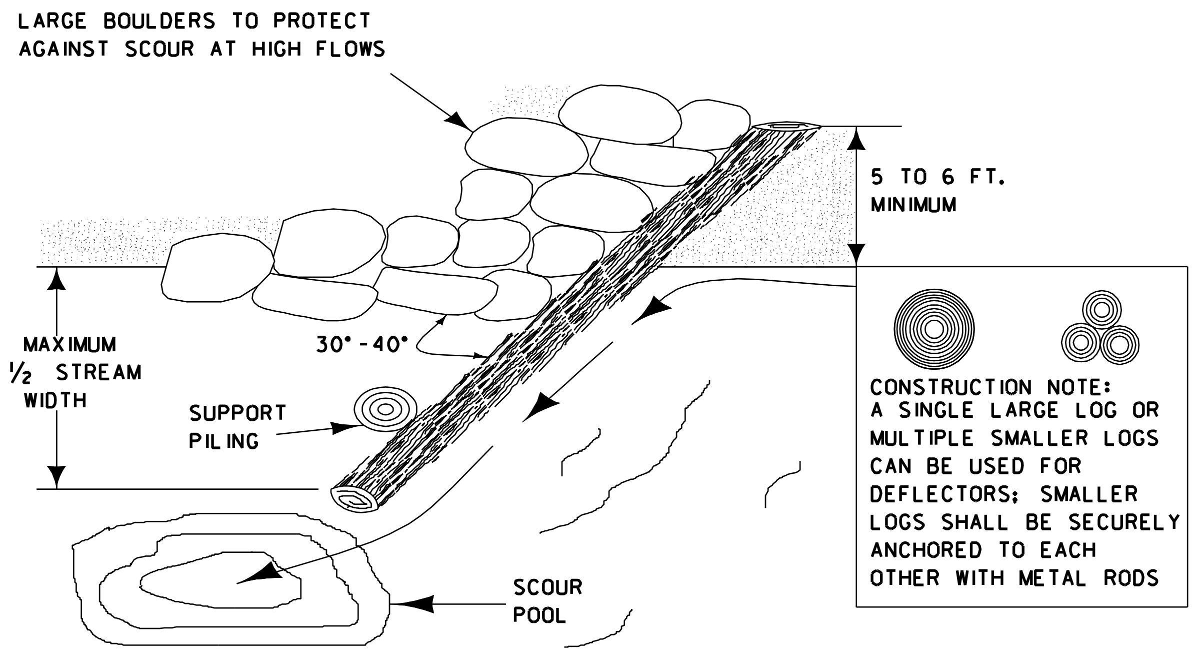
A SERIES OF WHOLE, DEAD TREES TABLED TOGETHER AND ANCHORED BY EARTH ANCHORS IN THE STREAMBANK.



APPLICATION AND PROPERTIES:
- SEMI-PERMANENT, HAS A LIMITED LIFE.
- USES INEXPENSIVE, READILY AVAILABLE MATERIALS.
- MAY REQUIRE PERIODIC MAINTENANCE TO REPLACE DAMAGES OR DETERIORATING TREES.
- HAS SELF-REPAIRING ABILITIES FOLLOWING DAMAGE AFTER FLOOD EVENTS IF USED IN COMBINATION WITH BIOTECHNICAL TECHNIQUES.
- SHOULD BE USED IN COMBINATION WITH OTHER BIOTECHNICAL TECHNIQUES.
- NOT APPROPRIATE NEAR BRIDGES OR OTHER STRUCTURES WHERE DOWNSTREAM DAMAGE IS POSSIBLE IF THE REVETMENT DISLODGES DURING FLOOD EVENTS.

Figure A12-2:

PLAN VIEW: LOG DEFLECTOR



SECTION VIEW: LOG DEFLECTOR

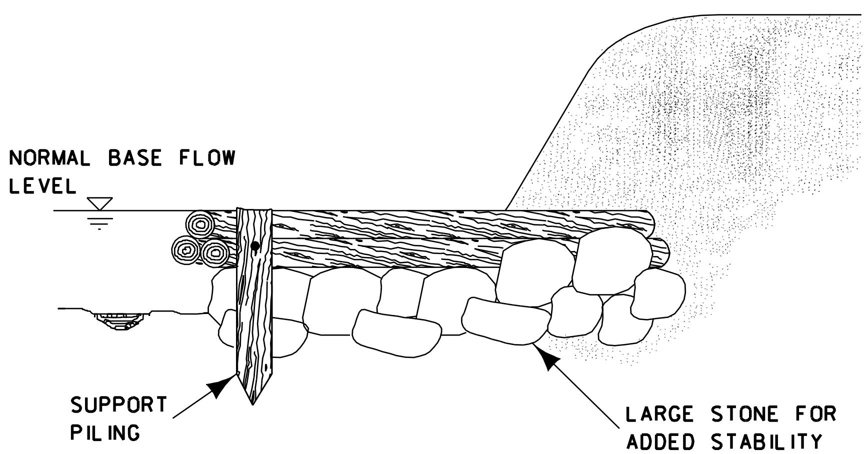
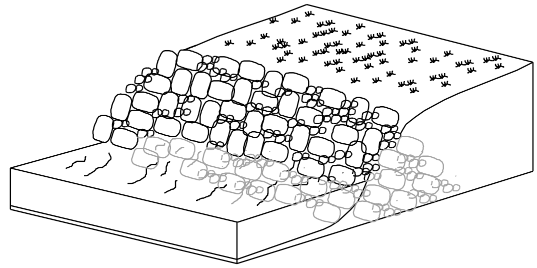


Figure A12-3: Log Deflector Views

TABLE C-1. BIOTECHNICAL TECHNOLOGIES
(Adapted from Li and Eddleman (2002) (continued).

JOINT PLANTING

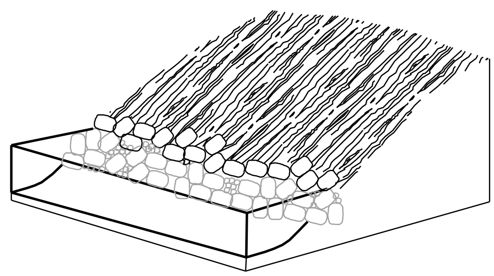
ROCK RIPRAPS WITH LIVE STAKES TAMPED INTO JOINTS OR OPENINGS BETWEEN ROCKS



APPLICATIONS AND PROPERTIES:
- ENHANCES AESTHETICS OF EXISTING ROCK RIPRAP.
- PROVIDES BETTER HABITATS THAN RIPRAP ALONE.
- IMPROVES THE STRENGTH OF RIPRAPS ALONE.
- PROVIDES IMMEDIATE PROTECTION AND IS EFFECTIVE IN REDUCING EROSION ON ACTIVELY ERODING BANKS.
- MANY AVAILIBLE DESIGN GUIDELINES BECAUSE THE RIPRAP IS WIDELY USED.

BRUSHMATRESS

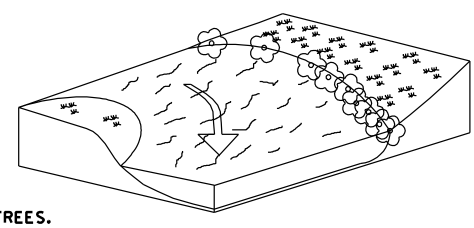
LIVE CUTTING INSTALLED WITH BRANCHES PARALLEL TO THE SLOPE DIRECTION TO FORM A MATTRESS. CUT ENDS OF LIVE CUTTINGS KEYED INTO THE TOE PROTECTIONAT THE SLOPE BOTTOM.



APPLICATIONS AND PROPERTIES:
- PROVIDES IMMEDIATE BUT LOW-STRENGTH PROTECTION ON STEAMBANKS.
- EFFECTIVE ON STEAMBANKS WITH STEEPNESS LESS THAN 50 PERCENT.
- CAPTURES SEDIMENT DURING FLOOD.
- RAPIDLY RESTORES RIPARIUM VEGETATION AND STREAMSIDE HABITAT.

TREE REVETMENT

A SERIES OF WHOLE, DEAD TREES TABLED TOGETHER AND ANCHORED BY EARTH ANCHORS IN THE STREAMBANK.



APPLICATION AND PROPERTIES:
- SEMI-PERMANENT, HAS A LIMITED LIFE.
- USES INEXPENSIVE, READILY AVAILABLE MATERIALS.
- MAY REQUIRE PERIODIC MAINTENANCE TO REPLACE DAMAGES OR DETERIORATING TREES.
- HAS SELF-REPAIRING ABILITIES FOLLOWING DAMAGE AFTER FLOOD EVENTS IF USED IN COMBINATION WITH BIOTECHNICAL TECHNIQUES.
- SHOULD BE USED IN COMBINATION WITH OTHER BIOTECHNICAL TECHNIQUES.
- NOT APPROPRIATE NEAR BRIDGES OR OTHER STRUCTURES WHERE DOWNSTREAM DAMAGE IS POSSIBLE IF THE REVETMENT DISLODGES DURING FLOOD EVENTS.

Figure A12-4:

A13.0: INTERCEPTOR DITCHES

A13.1 Definition and Purpose

Interceptor ditches—or furrow ditches—are utilized to intercept, divert, and convey surface water away from steep slopes (including cut and fill slopes) and discharge this surface water into a stabilized watercourse, drainage pipe, or channel. These ditches reduce the volume of water that is discharged into the roadside drainage system and protect slopes from excessive runoff and erosion. Interceptor ditches are ideal for collecting and dispersing surface water in a controlled manner.

A13.2 Appropriate Applications

Interceptor ditches may be utilized in areas where surface water is causing (or has the potential to cause) erosion on a steep slope. Berms may be used in combination with interceptor ditches in areas where runoff is hard to control or when constructed on a slope. Interceptor ditches should discharge into a stable area for collecting sediment. Interceptor ditches may be lined with asphalt, concrete, riprap, turf reinforcement mats (TRM), or coconut-fiber erosion control mats (ECM) in areas that are susceptible to erosion and/or where it is difficult to establish vegetation.

A13.3 Limitations

Interceptor ditches are not suitable as sediment trapping devices. Sediment-laden runoff should be discharged into a sediment trapping facility and/or treated in the ditch via check dams.

Interceptor ditches should not be placed adjacent to steep cut or fill slopes. Consult with the Geotechnical Section to determine the location of the interceptor ditch as well as to identify slope or soil stability concerns and recommendations.

A13.4 Design Considerations

- Coordinate with the Hydraulics Section to determine the size of ditches to convey the peak flow.
- Design and grade ditch and bank side slopes at a maximum 2H:1V ratio.
- Shape the ditch bottom so that it is trapezoidal or parabolic-shaped and at least 2 ft (0.6 m) wide to help slow and disperse water.
- Provide energy dissipation measures as necessary to prevent erosion at the ditch outlet.
- Interceptor ditches may be lined with asphalt, concrete, riprap, TRM, or ECM for slopes steeper than 2%, flow velocities greater than 5 ft/sec (1.5 m/sec), and/or areas that are susceptible to erosion or difficult to establish vegetation. Select the ditch liner according to the following slopes:

- Unlined: <2%
- Coconut-fiber ECM: 2% – 5%
- TRM: 5% – 8%
- Concrete and asphalt: >8%
- Riprap/grouted riprap: >8%

A13.5 Materials

No specialized materials are needed to construct interceptor ditches. If the ditch will be constructed in an area that is susceptible to erosion, then the designer should consider lining the ditch (see Section A6.0 - Lined Ditches). The designer should also evaluate the need for installing outlet protection for the ditch.

A13.6 Construction Considerations

- Remove all vegetation, roots, and rocks, and construct the ditch according to the design plans and specifications.
- Place outlet protection before—or in conjunction with—the construction of the ditch so that it is in place when the channel begins to operate.

A13.7 Operation and Maintenance

O and M costs for ditches are dependent on a number of factors such as:

- Size (length, width, and depth),
- Location (mountainous or prairie terrain), and
- Liners installed (if applicable).

Inspect embankments, beds, and outlets of ditches for erosion and accumulation of debris/sediment after major storm events. Remove debris/sediment, replace lost riprap, and repair ditches, linings, and embankments as necessary.

Regrade/reshape ditches for improving flow capacity, as necessary. Reseed immediately following grading activities.

A13.8 Initial Cost and Cost per Year

Initial Cost:	Low
Cost per Year:	Low

A13.9 Method of Payment

Interceptor ditches will be measured and paid by the linear foot (linear meter) of ditch installed.

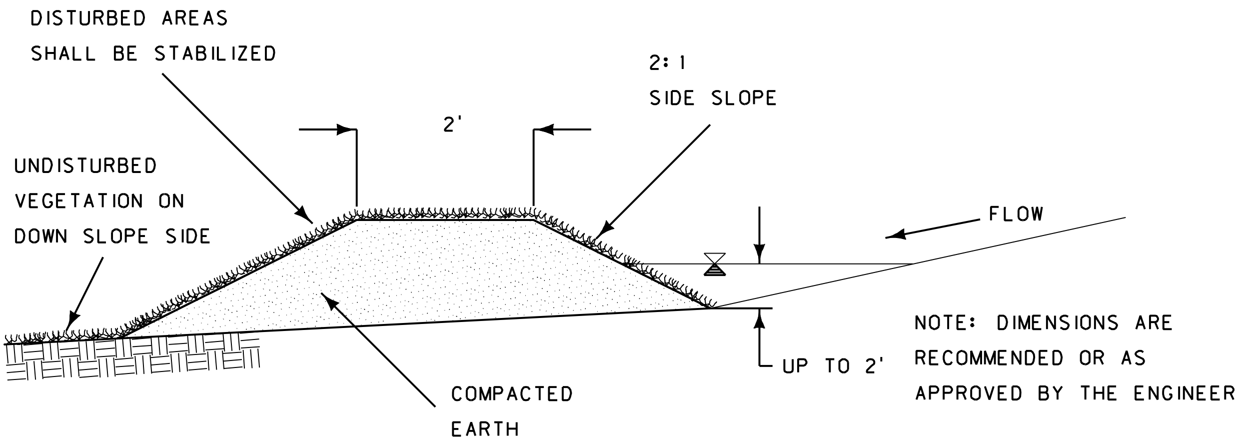


Figure A13-1: Interceptor Ditch

A14.0: TURF REINFORCEMENT MATS (TRM)

A14.1 Definition and Purpose

A Turf Reinforcement Mat (TRM) is a rolled permanent erosion product composed of UV-stabilized, non-degradable, synthetic materials. The materials may include an organic, bio-degradable fiber component processed into a three-dimensional matrix to add stability to soils. TRMs should be used where permanent erosion protection is needed and ECMs are not strong enough to withstand the anticipated flows.

A14.2 Appropriate Applications

- Used in ditches, swales, slopes and channels where design discharges exert velocities that exceed the limits of mature, natural vegetation to prevent erosion.
- Used in ditches and channels with steep gradients (5-8%), long runs (>100 ft – 30 m) or deep flows (>8 inches – 200 mm) where velocities will cause erosion mats to fail.
- Used in transition areas before and after hard armor (riprap, concrete, asphalt, etc.) to provide for stable and non-erosive transitions.
- Used as turf-reinforced slope drain in a channel with maximum slope of 4:1.
- Used as turf reinforcement mat on slopes steeper than 3:1 with limited growth potential.
- Contact the MDT Reclamation Specialist for types needed in the field for limited vegetation to have a chance to get established.

A14.3 Limitations

- Velocities should not exceed the limitations provided by the manufacturer.
- Maximum slope is dictated by the soil stability and the above-referenced limited velocity.
- Costs are often equivalent to riprap but give more of an aesthetic look to the site.

A14.4 Design Considerations

- TRM may be installed as either an on-the-surface or soil-loaded system (for surface, see Figure A14-1; for soil-loaded, see Figure A14-2).
- TRM should be unrolled in the direction of flow with edges overlapped a minimum of 4 inches (100 mm) and end of rolls overlapped a minimum of 6 inches (150 mm). Anchors for the TRM should be per manufacturer's recommendations for the particular TRM application and no less than 2 per square yard (square meter).
- TRM should extend 2 ft (0.6 m) minimum above the design maximum flow line in ditches and channels.
- Unless the TRM is anchored by a hard armor application, the leading edge of the TRM should be buried and anchored per Figure A14-3.

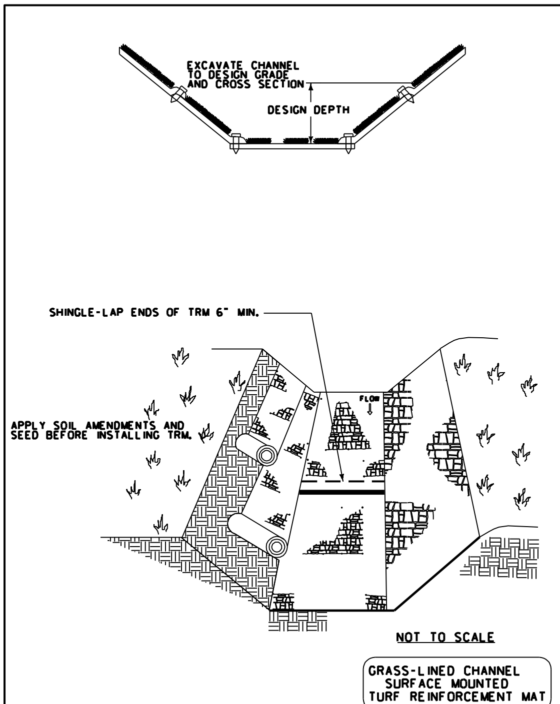
- The soil-loaded system should have no more than 2 inches (50 mm) of soil applied on the TRM.
- TRMs can be installed on top of established non-woody vegetation.

A14.5 Materials

The materials will be specific to the supplier.

A14.6 Construction Considerations

Install permanent channel erosion control mat in accordance with manufacturer's specification and MDT standard specification section 610. Follow manufacturer's staple pattern as marked on erosion mat for the applicable field situation.



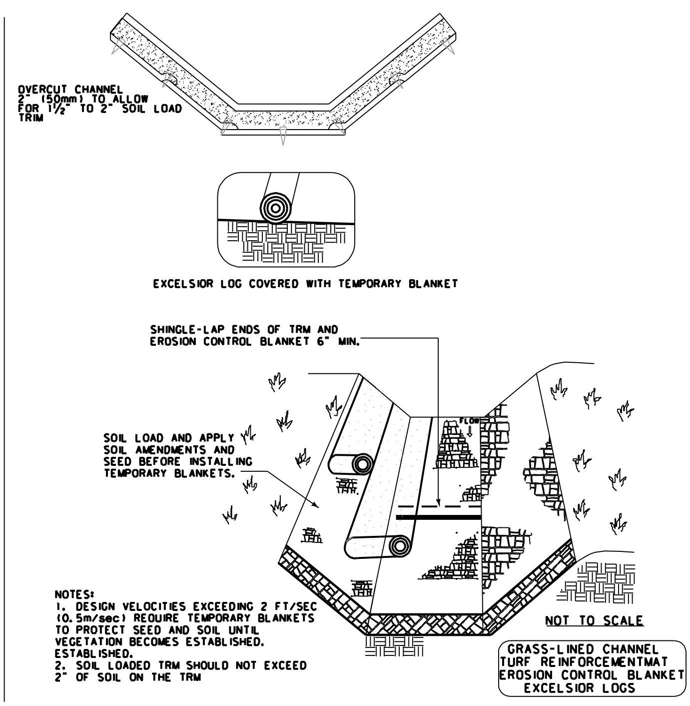


Figure A14-1: TRM on Surface Application

Figure A14-2: TRM Soil Loaded in Ditch Application with Mesh/Burlap Socks

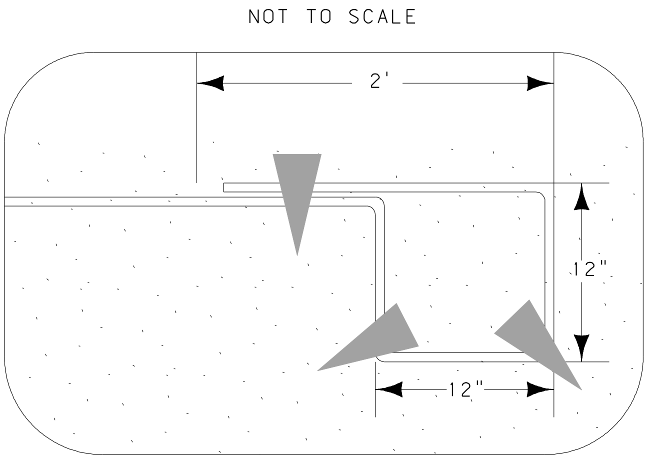


Figure A14-3: Trenching of TRM

A14.7 Operation and Maintenance

- Re-anchor loosened matting and replace missing matting and staples as required.
- Inspection should be performed periodically especially after a storm event that results in runoff, and any required repairs or maintenance should be performed immediately.

A14.8 Initial Cost and Cost Per Year

Initial Cost: High
Cost per Year: Low

A14.9 Method of Payment

TRMs are measured and paid by the square yard (square meter). All resources necessary to install the TRMs are included in the unit price bid.

A15.0: SETTLING BASINS

A15.1 Definition and Purpose

Settling basins are permanent dams or basins that can be used to enhance storm water runoff quality and reduce peak storm water runoff rates. Settling basins can be designed to maintain a permanent pool (wet pond) or to drain completely dry (detention or dry pond). Either way, the basin detains sediment-laden runoff long enough to allow most of the large sediment particles to settle out.

A settling basin can be constructed by excavation or by placing an earthen embankment across a low area or drainage swale. The pond has a riser and pipe outlet with a gravel outlet or spillway to slow the release of runoff and provide some sediment filtration.

A15.1.1 Dry Detention Basins

A dry detention basin is a storm water temporary storage basin that does not have a permanent pool. Dry basins receive storm water runoff and temporarily store (or detain) it for a short period of time as the captured water is slowly released. Dry detention basins can be incorporated in underground chambers, athletic fields, open spaces, etc., and are relatively easy to fit into a site. Dry detention basins are best used for reducing storm water runoff peak flow to an acceptable rate. Because dry detention basins have a tendency to re-suspend accumulated sediments, they are not the best choice for water quality protection. However, by providing “extended detention” (water quality volume [WQV] is discharged over 24 hours), dry detention basins can provide modest pollutant removal, mainly of coarse sediments.

A15.1.2 Wet Ponds

A wet pond is a sedimentation facility that has a permanent pool of water that is replaced with storm water, in part or in total, during storm water runoff events. In addition, a temporary detention volume is provided above this permanent pool to capture storm water runoff and enhance sedimentation. The influent water mixes with the permanent pool water as it rises above the permanent pool level. The wet pond is designed so that the surcharge captured volume above the permanent pool is released over a 12-hour period. Wet ponds require a dry-weather base flow to maintain the permanent pool. They can be very effective in removing pollutants, and, under the proper conditions, can satisfy multiple objectives.

A15.2 Appropriate Applications

A basin can be used to enhance storm water runoff quality and reduce peak storm water runoff rates. If the basins are constructed early in the development cycle, they can also be used to trap sediment from construction activities within the tributary drainage area. A basin can sometimes be retrofitted into existing flood control detention basins.

This Best Management Practice (BMP) can be effective in meeting the requirements of the Storm Water Management Program under the MS4 permit.

The dry detention basin performs well for reducing flow rates of small and large storm events. Dry detention basins can be sized to support small to large size drainage areas. Dry detention basins do not have the pollutant removal capability of wet ponds. However, dry detention basins with extended detention do a decent job in settling out coarse particles. Also, dry detention basins may be used as part of a “treatment train”; for example, as the pretreatment (sedimentation) basin to the surface sand filtration facility.

A wet pond can be used to improve the quality of urban runoff from roads, parking lots, residential neighborhoods, commercial areas, and industrial sites and is generally used as regional or follow-up treatment because of the base flow requirements. A wet pond works well in conjunction with other BMPs, such as upstream onsite source controls and downstream filter basins or wetland channels. A wet pond also can be easily adapted to provide quantity control for storms larger than the water quality storm event, require less periodic maintenance than other structural BMPs, and if desired can provide an amenity to a property such as “lakefront” residential property, wildlife habitat and fountain pools. Wet ponds seem to function better when the pond is larger and receives flow from a larger drainage area. Improved function may be attributed to several factors, such as the following:

- In larger drainage areas there is usually a better chance for seasonal or permanent surface or groundwater flow into the pond as opposed to smaller drainage areas. This flow may help the permanent pool to be “flushed” more often (as opposed to only during storm events), thereby preventing undesirable conditions (such as stagnant water, fluctuating permanent pool elevation, etc.) from developing.
- Wet ponds have a higher tolerance for runoff with sediment concentration than the other BMPs. Therefore, wet ponds are likely the preferred BMPs to use in large developments where construction will take place in phases or in residential development where site disturbance will occur for a period after the BMP is installed.
- For properties where the land may remain fully or partially unstabilized or if there are sources of sediments on the property (for example, gravel/dirt areas, areas where vegetation is slow to establish, etc.) the wet pond is a good choice.

A15.3 Limitations

- Safety concerns (such as clear zone issues, fencing near urban areas, etc.).
- Maintenance and sediment removal needs.
- Floating litter, scum, and algal blooms.
- Possible nuisance odors.
- Possible mosquito problems.
- Aquatic plant growth can be a factor in clogging outlet controls.
- The permanent pool can attract water fowl, which can add to the nutrient load entering and leaving the pond.

A15.4 Design Considerations

- Settling basins are typically designed by the Hydraulics Section. The road designer will review locations and ensure that the design details are included in the plans.
- Avoid placing these structures in environmentally sensitive areas such as perennial or intermittent streams and wetlands.
- The embankment slopes for open basins should be flatter than 3H:1V slope for safety and ease of maintenance. A 10-15 ft (approximately 3-4.6 m) bench (with maximum slope of 10%) placed around the pond near the normal pool surface is strongly encouraged. This bench will allow machinery to gain closer access to the pond during cleanouts. This break in the grade will be a safety amenity and can make the pond more aesthetically pleasing.
- Suitably designed vertical concrete walls may be used instead of earth embankments for open dry detention basins. In this case, it is recommended that a safety fence or other device be constructed around the basin perimeter to prevent accidents.
- When designing the dam and spillways, existing and potential future downstream development should be considered. Spillway design will be performed by the Hydraulics Section. Avoid placing the dam upstream of highly developed or traffic areas whenever possible. The discharge from the spillways should be directed to a conveyance system that can adequately handle the flow or, if no conveyance is present, the discharge should be directed away from existing development.
- The accumulated sediment will need to be removed after upstream land disturbances cease and before the basin is placed into final long-term use. The road designer will prepare a special provision to describe the removal of the material.

A15.4.1 Low Flow Orifices

Low flow orifices are designed to slowly release the volume stored in the basin. The release device may be a perforated riser, pipe with attached orifice plate, or skimming device. The designer should consider trash protection with any of these orifices.

A15.4.2 Spillways

Aboveground dry detention basins should have spillways designed to safely pass up to the 100-year storm event, at a minimum. Riser/barrel assemblies, concrete chutes, or riprap-lined channels may be used to pass larger storm events. Open channel spillways must not be placed in the fill section of earth dams. The spillways must have provisions to prevent erosion of the receiving conveyance.

A15.4.3 Basin Shape

Shape the pond whenever possible with a gradual expansion from the inflow area and a gradual contraction toward the outlet, thereby minimizing short circuiting. A basin length-to-width ratio between 2:1 and 3:1 is recommended. It may be necessary to modify the inlet and outlet points through the use of pipes, swales, or channels to accomplish this ratio. Always maximize the distance between the inlet and the outlet.

A15.4.4 Low-Flow Channel

Lining the low-flow channel with riprap is recommended, at least 9 inches (229 mm) deep if buried riprap is used. At a minimum provide capacity equal to twice the release capacity at the upstream forebay outlet.

A15.4.5 Basin Side Slopes

Basin side slopes should facilitate maintenance and access. Side slopes should be no steeper than 4:1 where practical.

A15.4.6 Dam Embankment

The embankment should be designed not to fail during a 100-year or larger storm. Embankment slopes should be no steeper than 3:1, and planted with turf-forming grasses. Poorly compacted native soils should be excavated and replaced.

A15.4.7 Vegetation

Bottom vegetation provides erosion control and sediment entrapment. Pond bottom, berms, and side sloping areas may be planted with native grasses or with irrigated turf, depending on the local setting.

A15.4.8 Maintenance Access

All-weather stable access to the bottom, forebay, and outlet controls area must be provided for maintenance vehicles. Maximum grades should not exceed 10% and should have a stable driving surface. Where possible, a gravel or hard surface should be provided.

A15.4.9 Inflow Point

Dissipate flow energy at the pond's inflow point(s) to limit erosion and promote particle sedimentation.

A15.4.10 Forebay Design

The Hydraulics Section will determine the need for a forebay. Forebays provide the opportunity for larger particles to settle out in the inflow area (the area that has a solid surface bottom) to facilitate mechanical sediment removal. A rock berm should be constructed between the forebay and the main extended detention basin. The forebay volume of the permanent pool should be about 5% of the design water quality capture volume. A pipe throughout the berm to convey water to the main body of the extended detention basin should be offset from the inflow streamline to prevent short circuiting and should be sized to drain the forebay volume in 15 minutes.

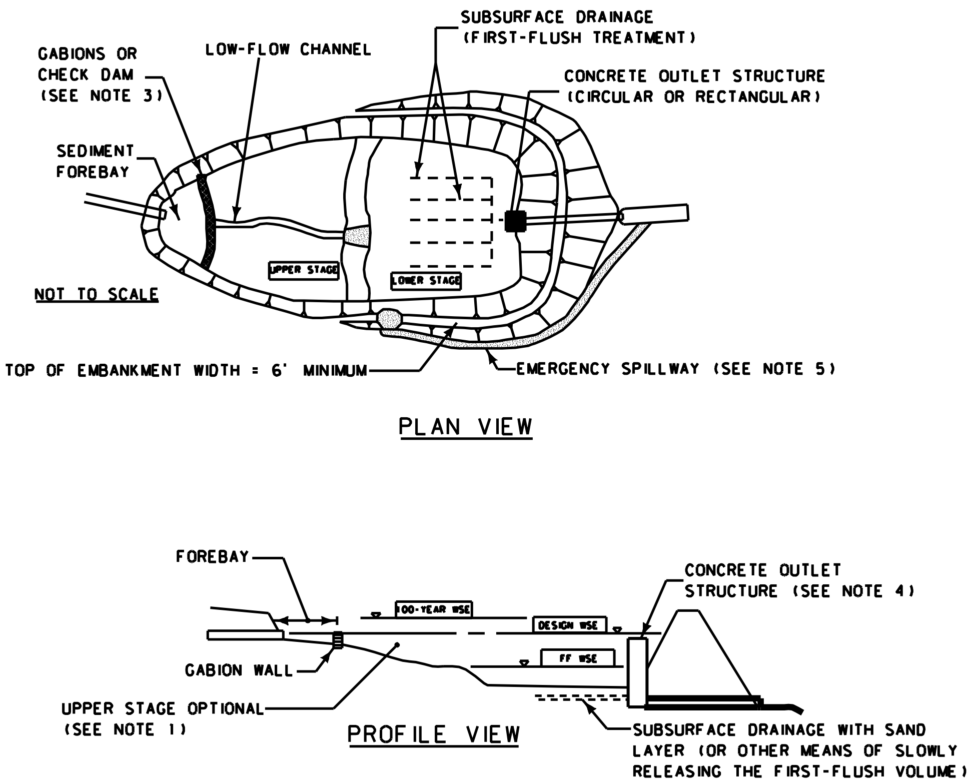
A15.4.11 Water Quality Volume

To design the basin for storm water quality control, the water quality volume (WQV) must be routed through the basin. The WQV is the amount of storm water runoff from any given storm that should be captured and treated in order to remove a majority of storm water pollutants on an average annual basis. The recommended WQV, which results in the capture and treatment of the entire runoff volume for 90% of the average annual storm events, is equivalent to the runoff associated with the first 1-inch of rainfall. This runoff is typically referred to as the “first-flush.”

A15.4.12 Wet Pond

The wet pond is designed similarly to the dry detention basin. The basin should be designed to reduce the peak flow from the 2-year storm and be able to pass a 100-year storm safely.

The permanent pool should be at least equal to the WQV for the watershed. The theory behind this requirement is that incoming runoff displaces old storm water from the basin and the new runoff is detained until it is displaced by more runoff from the next storm. A permanent pool equal to the WQV should then provide an adequate detention time for the storm water. Watershed size, soil conditions and groundwater elevation must be evaluated to ensure the capability of the site to support a permanent wet basin. To enhance pollutant and sediment removal, several other considerations may be taken into account, including a sediment forebay. The shape of the basin can affect the pollutant-removal efficiency. The length-to-width ratio should be at least 3:1. Basin depth should be between 5 and 10 ft (1.5 and 3.0 m); less could allow insect breeding and wind resuspension of settled particles, and more could lead to thermal stratification in the basin and anaerobic conditions in the deep water. A wedge-shaped basin, wider at the outlet, can also improve pollutant removal.



NOTES:

1. THIS EXAMPLE OF A TYPICAL DRY DETENTION BASIN LAYOUT SHOWS AN UPPER STAGE WHICH IS USED FOR STORMWATER DETENTION ON INFREQUENT STORMS. AN UPPER STAGE CAN ALSO BE LOCATED ON THE SIDE OF A DRY DETENTION BASIN, ELIMINATING THE NEED FOR A LOW-FLOW CHANNEL.

2. THE LOWER STAGE IS SIZED TO HANDLE THE FIRST-FLUSH VOLUME.

3. A FOREBAY CAN BE CONSTRUCTED FROM GABIONS, ROCK, CHECK DAMS, OR A SEPARATE BERM WITH CULVERT. A FOREBAY CAN FACILITATE THE CAPTURE AND CLEANUP OF COARSE SEDIMAMENT, DEBRIS, AND TRASH.

4. THE OUTLET STRUCTURE TYPICALLY HAS ORIFICES OR WEIRS AT COMPUTED ELEVATIONS THAT WILL RELEASE THE 1-YEAR, 2-YEAR, 5-YEAR, 10 YEAR, AND 25-YEAR STORMS AT THE SPECIFIED PRE-DEVELOPMENT PEAK FLOW RATES.

5. THE EMERGENCY SPILLWAY IS GENERALLY CONSTRUCTED ON NATURAL GROUND OR EXCAVATED AREAS (RATHER THAN FILL SOILS) TO REDUCE THE POTENTIAL FOR EROSION AND WASHOUT.

6. THERE ARE SEVERAL TYPES OF FIRST-FLUSH AND OUTLET STRUCTURES AVAILABLE. THE DESIGNER SHOULD CHECK WITH THE DESIGN REVIEWING AUTHORITY BEFORE SUBMITTING NOVEL OR ALTERNATIVE DESIGN APPROACHES.

Figure A15-1: Dry Detention Basin

A15.5 Materials

Materials required will vary with site-specific conditions.

A15.6 Construction Considerations

Unclassified excavation can be used for the construction of dry basins and muck excavation may be necessary for the construction of wet ponds. If the settling basin is constructed early in the project construction process, construction-related sediment may need to be removed before project completion.

A15.7 Operation and Maintenance

Basins should be inspected annually. Remove sediment as necessary to ensure proper function.

A15.8 Initial Cost and Cost Per Year

Initial Cost:	High
Cost per Year:	Moderate

A15.9 Method of Payment

Materials required for construction will be paid at appropriate unit prices.

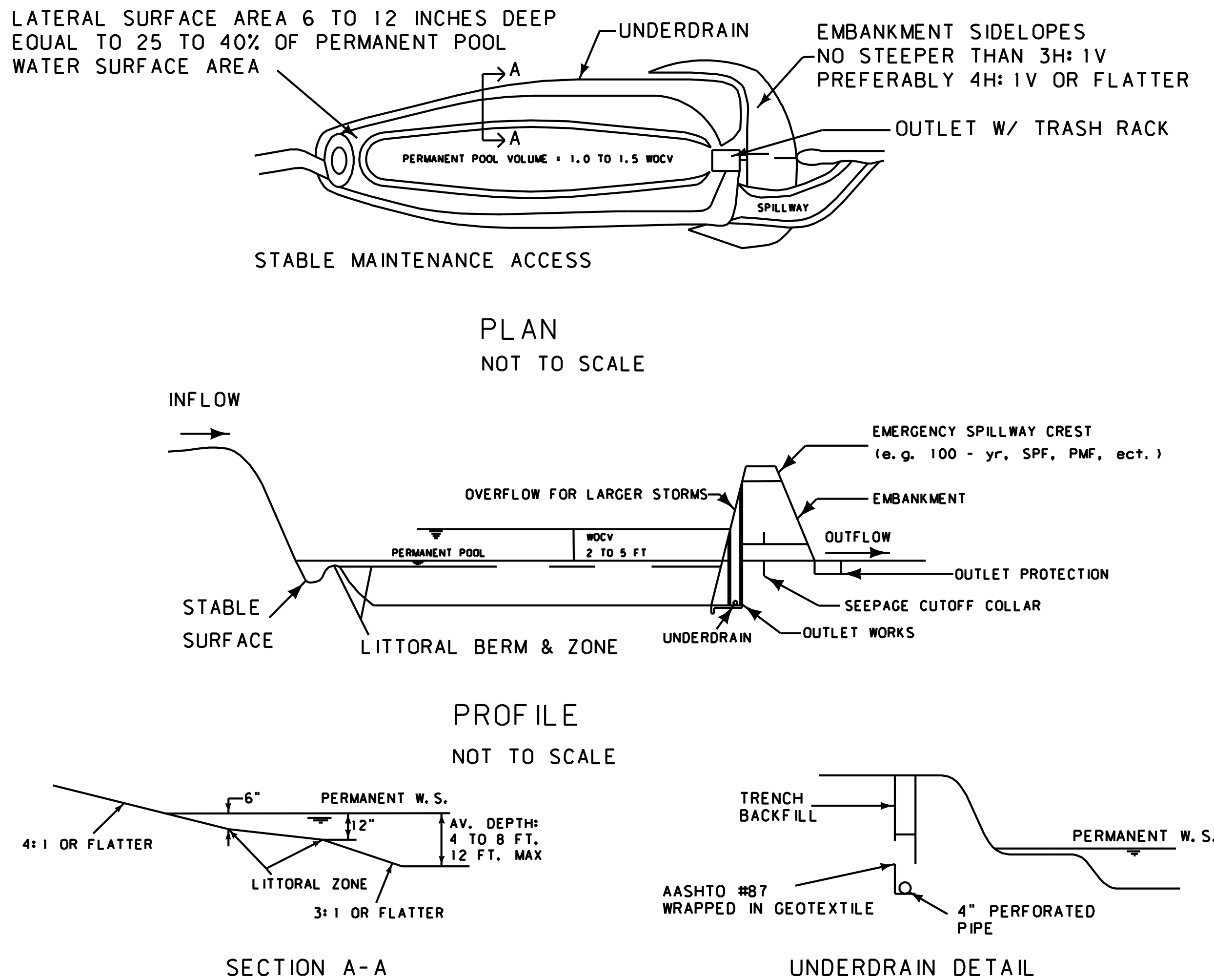


Figure A15-2: Wet Retention Basin

A16.0: INFILTRATION BASINS

A16.1 Definition and Purpose

An infiltration basin is a shallow impoundment that captures and stores storm water until it can infiltrate into the soil. The soil acts as a natural filter to remove pollutants from the storm water before it eventually reaches the water table. Infiltration systems have high pollutant removal efficiency for constituents including fine sediments, nutrients, trash, metals, bacteria, oils, greases, and organics. Some soluble constituents can be effectively removed if proper vegetation is planted and managed, and detention time is maximized.

Infiltration basins offer benefits in addition to storm water control. One benefit is groundwater recharge that may augment base stream flow. Infiltration basins can effectively replace infiltration loss due to addition of impervious areas, and may be used strictly as a means to maintain the natural (pre-development) hydrologic balance of a site. Multiple uses of infiltration systems are recommended when and where practicable.

A16.2 Appropriate Applications

Use: Infiltration basins are used where outfalls are not available, such as developed areas and urban interchanges. (See A16.3 Limitations discussion below for appropriate distance between basin and structures.)

Drainage Area: Infiltration basins typically serve drainage areas from 5-50 ac (2-20 ha). For drainage areas less than 5 ac (2 ha), infiltration trenches are generally used. For drainage areas greater than 50 ac (20 ha), detention or wet ponds are generally used.

Soil Type: Soil type at the site will play an important role in determining if an infiltration basin is the preferred PESC. Acceptable soils are generally Department of Natural Resources and Conservation (DNRC) soil types A or B. The soils should have an infiltration rate of at least 0.5 inch/hr (13 mm/hr). Soils should be comprised of less than 30% clay or less than 40% clay and silt combined. Infiltration basins will have higher potential for success when they are sited based on site-specific field data rather than on soil survey tables and mapping alone. (Please see Key Siting Criteria in Section A16.4 below.) A minimum of 4 ft (1.2 m) from the basin bottom to bedrock is recommended.

Depth to Groundwater: Groundwater separation should be at least 10 ft (3 m) from the basin invert to the measured groundwater elevation. In the absence of site-specific data, consult US Department of Agriculture (USDA) soil survey tables to investigate the presence of a restrictive layer or seasonal high water table. A minimum of 4 ft (1.2 m) from the basin bottom to the seasonally high water table is recommended in order to ensure proper basin operation.

A16.3 Limitations

Soils: Restoring the functioning of a clogged infiltration basin can be difficult. If soil conditions do not match those listed in the A16.2 Appropriate Applications section, use a different PESC measure.

Pretreatment: Pretreatment may be necessary to minimize risk of groundwater contamination or to minimize maintenance requirements due to clogging of the basin. Consider use of a pretreatment measure (such as a sediment basin or oil/grit separator) or use of a PESC measure other than an infiltration basin for:

- Project sites near industrial sites, chemical or pesticide storage areas, or fueling stations;
- Areas with very coarse soils [where infiltration rates exceed 2.4 inch/hr (60 mm/hr)]; or
- Areas where coarse sediments or oils are expected.

Location: Site-specific location conditions will play an important role in deciding if an infiltration basin is the appropriate PESC measure. Do not site infiltration basins:

- In or partially in fill sites (unless no silts or clays are present in a soil boring);
- On steep (greater than 15%) slopes;
- In areas where the slope of the contributing watershed is greater than 20%;
- Closer than 20 ft (6 m) from buildings, fill slopes or highway pavement; or
- Closer than 100 ft (30 m) up-gradient or 20 ft (6 m) down-gradient from drinking water wells or bridge structures.

A16.4 Design Considerations

Design: Infiltration basins are typically designed by the Hydraulics Section. The road designer will review locations and ensure that the design details are included in the plans.

Key Siting Criteria: Appropriate soil and hydrogeologic properties are critical for long-term successful performance. If soil and hydrogeologic conditions do not match those listed in the A16.2 Appropriate Applications section, use a different PESC measure.

Successfully siting the infiltration basin will likely require coordination with the MDT Geotechnical Bureau to gather site-specific soils and hydrogeologic data. When possible, use the following site-specific geotechnical investigations to evaluate the site.

- At least three in-hole conductivity tests should be performed using USBR 7300-89 or Bouwer-Rice procedures (the latter if groundwater is encountered within the boring). Another method may be substituted as determined in consultation with the MDT Geotechnical Bureau. Two of the tests should be at different locations within the proposed basin and the third down-gradient by no more than approximately 33 ft (10

m). The tests measure permeability in the side slopes and the bed within a depth of 10 ft (3 m) of the invert.
- The minimum acceptable hydraulic conductivity as measured in any of the three required test holes is 0.5 inch/hr (13 mm/hr). If any of the three test holes shows less than the minimum value, the site should be disqualified from further consideration.
- The geotechnical investigation should be such that a good understanding is gained as to how the storm water runoff will move in the soil (horizontally or vertically) and if there are any geological conditions that could inhibit the movement of water.

Volume: Minimum design volume should be determined by local requirements or sized to capture no less than the water quality volume (WQV) from the entire contributing watershed. Larger design volumes are recommended, as they will provide treatment that is more effective.

Holding Time: The basin should be sized to infiltrate the entire WQV in 6-72 hours. Less than 6 hours of holding time provides little treatment, while greater than 72 hours can create nuisance and capacity problems for back-to-back storms. Many sources recommend sizing the basin for infiltration of the entire WQV in 48 hours.

Buffer Strip: A 25-foot (7.6 m) vegetated buffer strip should surround the infiltration basin to provide pretreatment and to ensure adequate access for maintenance. Consult the MDT Reclamation Specialist for specific seeding/planting guidelines.

Basin Configuration: An infiltration basin may be constructed in any shape to meet right-of-way restrictions. The basin floor should be as flat as possible with no noticeable depressions. Side slopes should be no more than 3:1 (h:v) to allow for mowing and other necessary maintenance. As appropriate with consideration to right-of-way needs, maximize basin floor surface area and reduce depth to optimize infiltration.

Emergency Spillway: Provide an emergency spillway in order to direct overflows from storms larger than the design storm.

Energy Dissipation: Provide energy dissipation (generally riprap) at inlets and outlets to prevent scouring, reduce flow velocities, and trap sediment.

Vegetation: Established vegetation can maintain and possibly improve infiltration, prevent erosion, and remove soluble nutrients in the storm water. Vegetation on the basin bottom and sides must be capable of surviving up to 72 hours under water. Tall fescues or bermuda grass are often used. Consult the MDT Reclamation Specialist for specific seeding/planting guidelines.

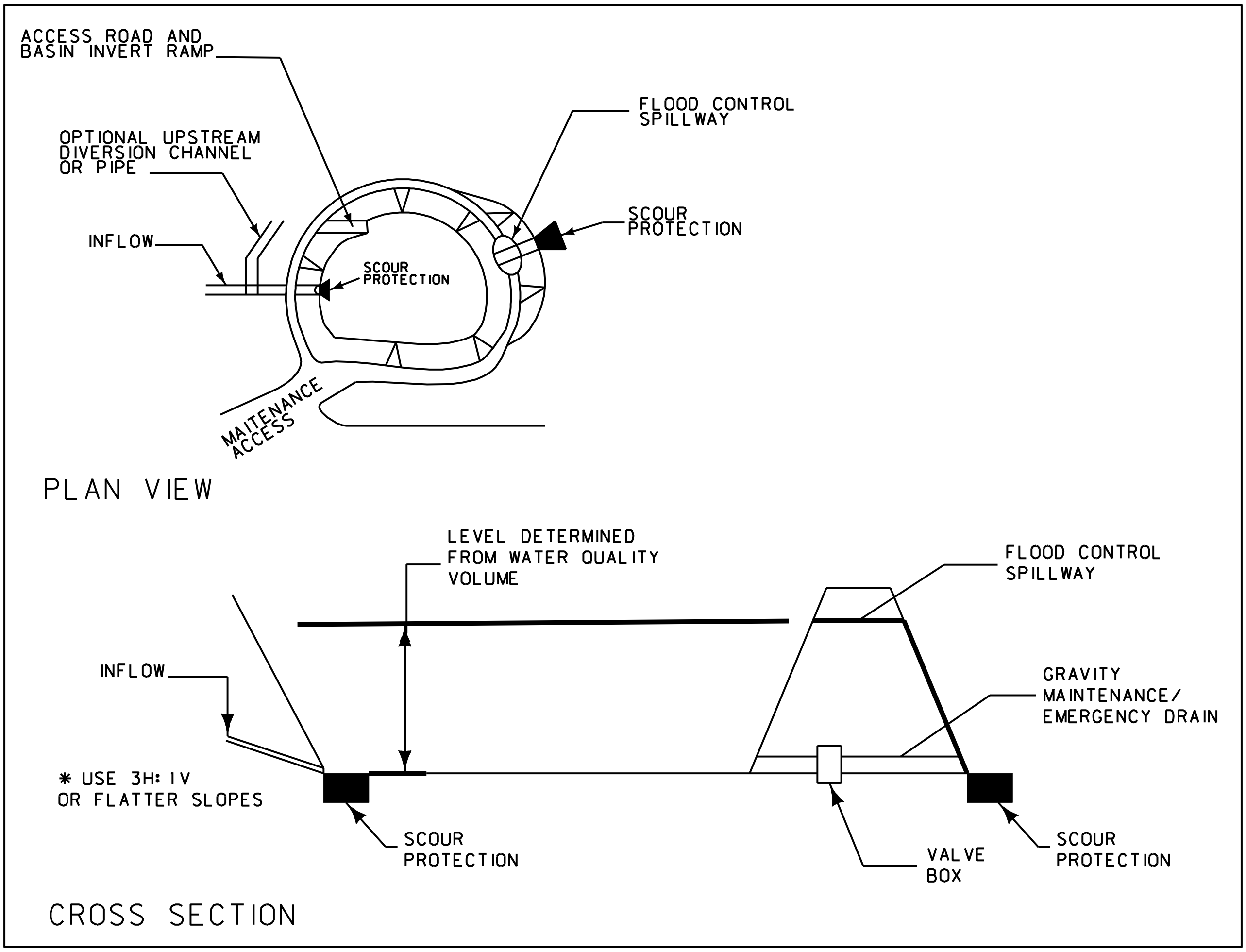


Figure A16-1: Infiltration Basin General Schematic
(Note that the low flow channel is not shown.)

A16.5 Materials

Consult the MDT Reclamation Specialist for specific seeding/planting guidelines.

A16.6 Construction Considerations

Without precautions, sediments from the construction site can clog the basin, preventing post-project infiltration. Preferably, the basin would not be put into use until after the work site and the area draining to the basin are stabilized.

If the infiltration basin will also serve as a sediment basin during construction, it should only be excavated down to about 2 ft (0.6 m) above the infiltration basin design floor. Sediment that accumulates in the basin can then be excavated after all other construction is complete.

- A temporary diversion berm around the perimeter of the infiltration basin is recommended to prevent sediment entrance during construction and until the basin vegetation is established.
- Prior to any site construction, rope off the infiltration area to prevent entrance by unwanted equipment.
- Place excavated material such that it cannot be washed back into the basin if a storm occurs during construction of the facility.
- To prevent soil compaction, build the basin without driving heavy equipment over the infiltration surface. Equipment driven on the surface should have extra-wide ("low pressure") tires.
- After final grading, till the infiltration surface deeply.

A16.7 Operation and Maintenance

Maintenance and inspection are essential for the long-term successful operation of this PESC. Goals of inspections and maintenance should be to ensure that water infiltrates into the subsurface within 72 hours or less and that vegetation remains healthy. Recommended operation and maintenance guidelines include:

- Observe drain time for the design storm after completion or modification of the facility to confirm that the desired drain time has been obtained.
- Schedule semiannual inspections for the beginning and end of the wet season to identify potential problems such as erosion of the basin side slopes and invert, standing water, trash and debris, and sediment accumulation.
- Remove accumulated trash and debris in the basin at the start and end of the wet season.
- Inspect for standing water at the end of the wet season.
- Trim vegetation at the beginning and end of the wet season to prevent establishment of woody vegetation.
- Remove accumulated sediment and re-grade when the accumulated sediment volume exceeds 10% of the basin.
- If erosion is occurring within the basin, revegetate immediately and stabilize with an erosion control mulch or mat until vegetation cover is established.
- To avoid reversing soil development, scarification or other disturbance should only be performed when there are actual signs of clogging, rather than on a routine basis. Remove deposited sediments before scarification. For scarification, use a hand-guided rotary tiller, if possible, or a disc harrow pulled by a very light tractor.

A16.8 Initial Cost and Cost per Year

Initial Cost:	Moderate
Cost per Year:	Low

A16.9 Method of Payment

Materials required for construction will be paid at appropriate unit prices.

A17.0: POROUS PAVEMENTS

A17.1 Definition and Purpose

This structural BMP consists of porous asphalt, concrete, lattice pavers, concrete blocks, or stones. The surface material is laid on a gravel subgrade and the surface voids are filled with sand or a sandy loam turf. Storm water flow percolates through the pavement into the underlying soil. Using this BMP, streets, parking lots, sidewalks, and other impervious surfaces retain their infiltration capacity. This is also known as “the Green Parking technique” for its environmental friendliness.

A17.2 Appropriate Application

- Used in areas of low traffic volumes and loads.
- Used in urbanized areas.
- Porous pavements function to decrease the effective imperviousness of a project site. Most often used in the construction of parking lots for rest areas.
- Other uses include traffic islands, emergency stopping areas, road shoulders, residential driveways, sidewalks and maintenance roads.
- Lattice pavers, blocks, or stones can enhance site aesthetics.
- Used to reduce flooding by infiltrating or slowing storm water runoff.
- Filters some particulate pollutant from runoff if maintained properly.
- Less need for curbing and storm sewers in area.
- Green Parking treats and stores storm water without consuming extra land.
- Increases groundwater recharge in urbanized area without loss of service.

A17.3 Limitations

- Very high maintenance required.
- Careful attention to maintenance is necessary to reduce clogging. Maintenance should include vacuum sweeping and jet hosing.
- Initial pollutant removal rates are high but decrease as the porous materials become clogged.
- Suitable sites are generally limited to low traffic areas with a soil infiltration capacity of 0.5 inch/hr (13 mm/hr).
- Porous pavements should not be used in areas of high contaminant loads such as gas stations due to risk of contaminating the aquifer.

- Many people do not have the expertise to properly design this technology.
- Less than 15 acre (6.1 ha) area.
- Snow removal difficulties.
- Weed and grass may become issues within fill area.
- In cold climates, subbase needs to extend below frost line to minimize frost heave.

A17.4 Design Considerations

- Pavement thickness should be sufficient to protect the subgrade.
- Quality base and subbase materials should be used to support the applied loads.
- Underlying subbase soil must remain uncompacted for proper infiltration to occur.
- Do not use if subbase soils have <0.27 inch/hr (7 mm/hr) permeability.
- Adjacent unpaved areas should be stabilized to prevent sediment from washing into the porous pavement area.
- Grass buffer zone is recommended to prevent additional sediment from entering project site.

A17.5 Materials

- Open celled paving grids.
- Open jointed paving blocks.
- Plastic geo-cells and grass growing throughout.
- Porous asphalt pavement.
- Pervious concrete pavement.

A17.6 Construction Considerations

Install pavers, blocks and geo-cells according to the manufacturer's recommendations.

A17.7 Operation and Maintenance

- Control of sediment is critical for system not to fail.
- Need to maintain by vacuum sweeping and disposal of removed material three times per year.
- Use high pressure hosing to keep pores in top layer from clogging.
- Limited snow plow area as top surface can be damaged by plows.
- Do not use sand or deicing chemicals in project area.

Reference: Denver Urban Drainage and Flood Control District, Volume 3 Criteria Manual.

A17.8 Initial Cost and Cost Per Year

Initial Cost: High
Cost per Year: High

A17.9 Method of Payment

Porous pavements will be paid at the unit price per square yard (or meter).

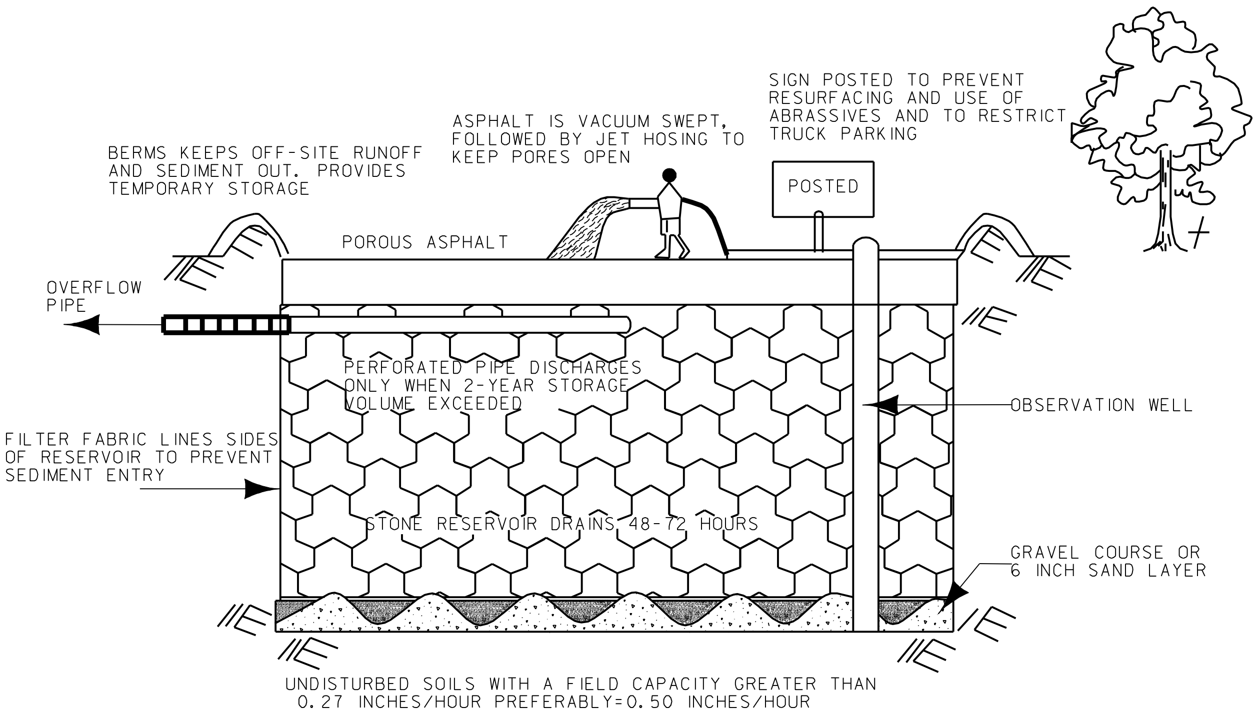


Figure A17-1: Porous Pavement Construction

A18.0 CONSTRUCTED WETLAND BASINS (CWB)

A18.1 Definition and Purpose

A constructed wetland basin (CWB) (or wet basin) is a detention system comprised of a permanent pool of water, a temporary storage volume above the permanent pool, and a shoreline zone planted with aquatic vegetation. The CWB requires a perennial base flow to encourage and maintain the growth of rushes, willows, cattails, and reeds. It is a sedimentation basin and also serves a second function of treating the storm water, removing pollutants before discharge. CWBs are effective in removing sediments, nutrients, particulate metals, pathogens, litter and Biochemical Oxygen Demand (BOD) by temporarily capturing and detaining the Water Quality Volume (WQV) in order to allow settling, filtering, and biological uptake to occur.

A CWB can be used as a structural BMP in a watershed or as a stand-alone onsite facility. In a stand-alone situation, the owner must provide sufficient water to sustain the wetland. Flood control storage can be provided above the basin's WQV pool to act as a multiuse facility.

A18.2 Appropriate Applications

CWBs are permanent pools of water designed to mimic naturally-occurring wetlands. The main distinction between constructed and natural wetlands is that constructed wetlands are placed in upland areas and are not subject to wetland protection regulations. Wet basins should be considered when the site is located where the visual aesthetics of the permanent pool are considered a benefit (such as a roadside rest area or vista point) or where the added treatment the basin provides will be of benefit (such as areas where the basin will discharge to water quality sensitive areas or runoff is from areas likely to contain pollutants in addition to sediment).

This measure may also be a requirement or at least a consideration in urban areas where an MS4 program is in place. Inclusion of such measures in the MDT design will assist in complying with requirements under the Post Construction Storm Water Management aspects of the permit.

A CWB offers several potential benefits such as natural aesthetic qualities, wildlife habitat, erosion control, and pollutant removal. It can also provide an effective follow-up treatment to onsite and source control BMPs that rely upon settling of larger sediment particles. In other words, it offers yet another effective structural BMP for larger tributary catchments.

A18.3 Limitations

- **Flow** - The primary drawback of the constructed wetland is the need for a continuous base flow to ensure viable wetland growth. The site must have a high water table or another source of water must be present to provide base flow sufficient to maintain the plant community year-round.

- **Maintenance** - Silt and scum can accumulate and unless properly designed and built, can be flushed out during larger storms. Along with routine good housekeeping maintenance, occasional “mucking out” will be required when sediment accumulations become too large and affect performance. Periodic sediment removal is also needed for proper distribution of growth zones and of water movement within the wetland.

- **Capacity Limitations** - In order to maintain a healthy wetland growth, the surcharge depth for WQV above the permanent water surface cannot exceed 2 ft (0.6 m).

- **Pollutants** - Pollutants are removed through sedimentation and entrapment with some removal through biological uptake by vegetation and microorganisms. Without a continuous dry-weather base flow, salts and algae can concentrate in the water column and can be released into the receiving water in higher levels at the beginning of a storm event as they are washed out.

- **Additional Right-of-Way** - Because of the size of the measure, additional right-of-way may need to be obtained to construct the wetland.

A18.4 Design Considerations

- The designer must coordinate with the district biologist and the district hydraulics engineer. An analysis of the water budget is needed to show that the net inflow of water is sufficient to meet all the projected losses (such as evaporation, evapotranspiration, and seepage for each season of operation). Insufficient inflow can cause the wetland to become saline or to die off.
- Within the wet basin, a flow-path-to-width ratio of at least 2:1 configured in an irregular or meandering configuration must be provided. The invert of the wet basin may employ a 'micro topography' (contouring and benching of the invert to vary the water depth); care should be exercised to minimize stagnant areas (areas where incoming water does not displace or commingle with permanent pool). The basin may also be configured to fit the surrounding topography.
- For the ground above the WQV elevation, use 4:1 side slope ratios or flatter for a minimum 16 ft (3 m) horizontally, with 3:1 side slopes maximum if approved by Maintenance. Below the WQV and the permanent pool elevation, the side slope ratios should be no steeper than 3:1, and 4:1 is preferred along the entire shoreline. Within the wet basin, average water depth should be approximately 3.9 - 6.6 ft (1.2 - 2 m), and typical maximum depth between 8 and 10 ft (2.4 and 3.1 m). Usually the shallow (vegetated) areas are limited to between 25 and 50% of the surface water area of the wet basin. See the table and figure below.

Table A18-1: Constructed Wetland Hydrologic Zones

Zone	Description and Topography	Hydrologic Condition and Water Depths Between Storm Events
1	Deep water pool (permanent pool; not used in all wet basins); volume of up to 25% of WQV; up to 35% of surface area; flat slopes, or slopes up to 1:3 where adjoining Zone 2.	1 - 6 ft (0.3 - 1.8 m); little or no plant growth in this zone, *especially between depths of 1.6 – 3.3 ft (0.5 -1.0 m).*
2	Shallow water bench (permanent pool); 35-75% of surface area; side slopes up to 3:1.	0.5 - 1 ft (0.15 - 0.3 m); hydrophytic plants in this zone.
3	Shoreline fringe (could also include any upstream forebay to the wet basin); 25-40% of surface area; side slopes up to 3:1.	Regularly inundated during rainy season (conceptually, frequent storm events); this zone is sized to hold the WQV; depth is project-specific; hydrophilic plants in this zone.
4	Riparian fringe; side slopes of 4:1 (up to 3:1 if approved by Maintenance).	Periodically inundated (conceptually, up to 10-year storm events).
5	Floodplain terrace; no set side slope ratio.	Infrequently inundated.
6	Upland slopes; no set side slope ratio.	Rarely or never.

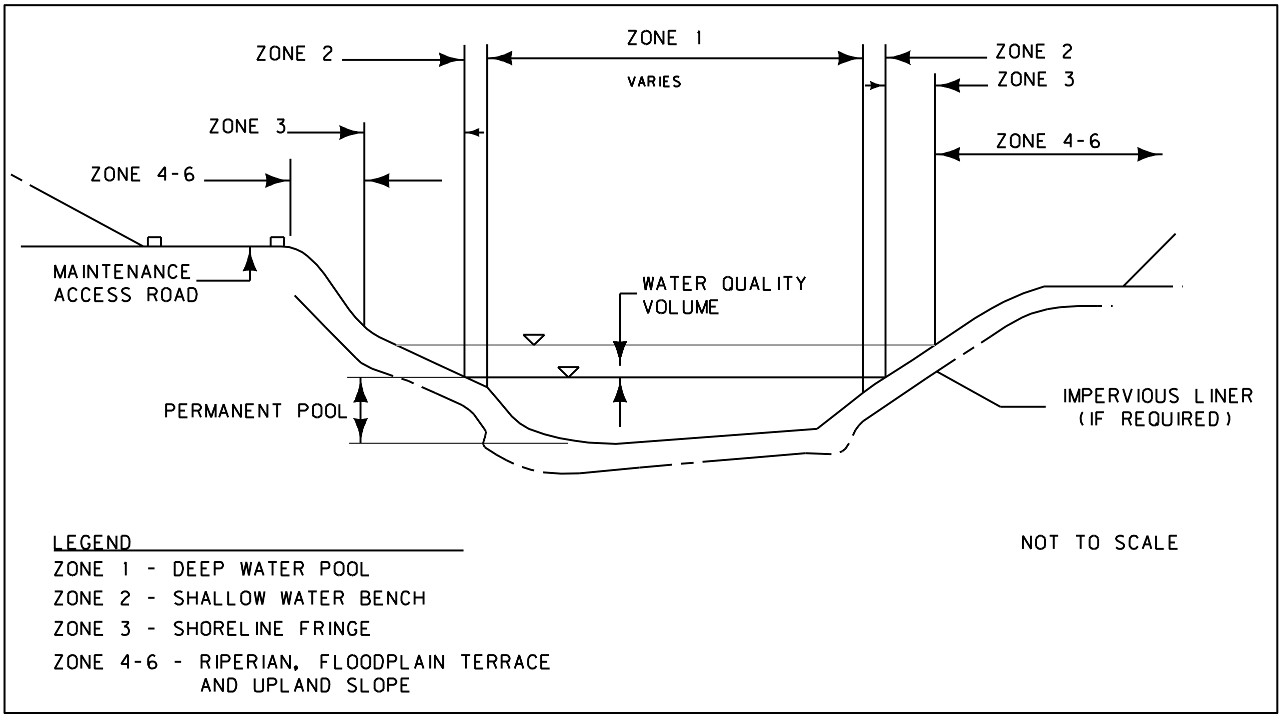


Figure A18-1: Constructed Wetland Basin

- The outlet used to discharge the WQV is designed to complete the drawdown in 24-72 hrs, but typically 24-48 hrs. The WQV outlet should employ a debris screen (or equivalent) and riser. In addition to a device that safely discharges the WQV, an outlet device must pass the largest event that could reach the basin, which may be done using the same device that will discharge the WQV, or by a separate device.
- The wet basin should have a freeboard greater than or equal to 12 inches (300 mm), where freeboard is defined as the distance between the elevation at the top of the containment forming the basin, and the water surface elevation of the largest storm that can enter the basin. It is assumed that when that storm is passing through the wet basin, the initial water surface elevation in the wet basin includes the WQV retained above the permanent pool.
- The design for the wet basin must provide appropriate vegetation for each hydrologic zone. Native soils at invert may require added organics.
- Consider fencing around the wet basin to restrict public access.

A18.5 Materials

The materials will vary with the specific site conditions and wetland design, but the following items are typically included in most wetland designs:

- Grading – unclassified excavation or muck excavation
- Seeding and plantings
- Wetland soil salvage
- fencing

A18.6 Construction Considerations

The following items need to be considered for wetland construction:

- Ensure that Tribal requirements and/or Corps of Engineers' special conditions contained in the 404 permit are met.
- Constructing the wetland to the design elevations is essential for the development of the wetland
- Ensure that the stockpile sites for normal grading material and wetland soils are separate
- When the wetland is constructed as a stand-alone project the disposal of the excavated material needs to be addressed
- Special sequencing may be necessary when the wetland is constructed in conjunction with a road project if the excavated material is to be used in the construction of the roadway.

A18.7 Operation and Maintenance

- Inspect after each major storm, and at least once per year. Once wetland vegetation is established and basin performance is consistent, storm event inspection can likely be eliminated.
- Inspect outlet for erosion and downstream scour. If eroded, repair damage and install additional energy dissipation measures. If downstream scour is occurring, it may be necessary to reduce flows being discharged into the outfall area unless other preventative measures are implemented.
- Inspect inlet for accumulations of debris and sediment.
- Remove built-up sediment from inlet, outlet and elsewhere as required.

A18.8 Initial Cost and Cost Per Year

Initial Cost:	High
Cost per Year:	Low to Moderate

A18.9 Method of Payment

The construction of the wetland will usually be paid as a lump sum. However, depending on the situation the wetland construction may be paid at the unit prices bid for individual items.

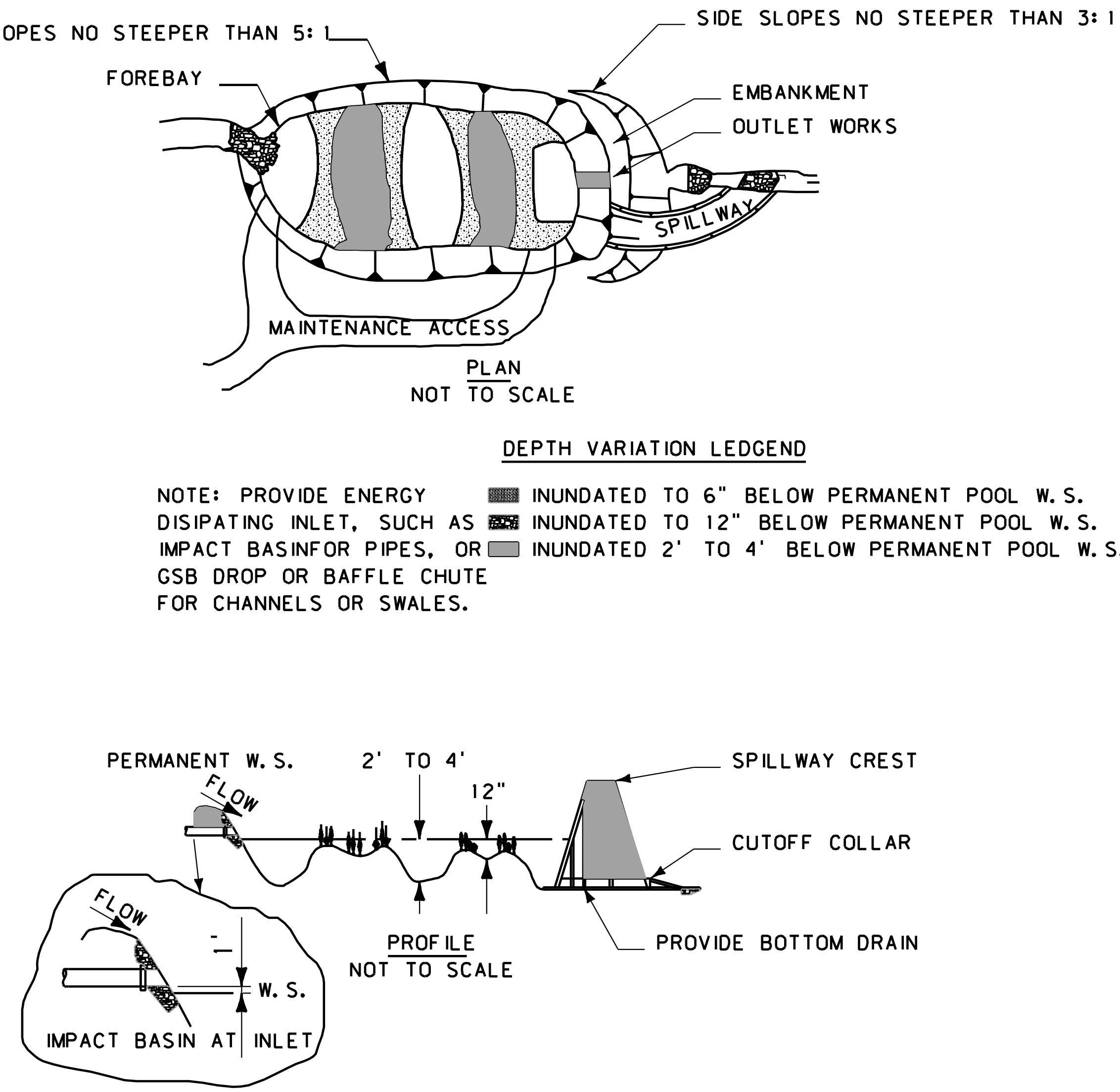


Figure A18-2: Plan and Profile Views of Constructed Wetland Basin

A19.0: NATURAL AND ENGINEERED DISPERSION

A19.1 Definition and Purpose

There are two types of dispersion: natural dispersion and engineered dispersion.

Natural Dispersion **Engineered Dispersion**

Natural dispersion is a practice where existing well-vegetated and gently sloping (≤15%) sites are identified and preserved to receive and infiltrate storm water runoff.

Engineered dispersion is a practice where the site to receive and infiltrate storm water runoff is designed and constructed.

The key to effective natural and engineered dispersion is that flows from the impervious area enter and flow through the dispersion area as sheet flow. Storm water runoff that is collected and concentrated in a ditch or pipe can also be discharged to a dispersion area, but the channelized flow must first be re-dispersed along the upstream length of the dispersion area using rock pads, gravel-filled dispersion trenches, level-lip spreaders, etc.

The benefits of natural and engineered dispersion include the following:

- Maintains and preserves natural functions.
- Can be very cost-effective.
- Provides runoff treatment, sediment removal and erosion control.
- Can be used for maintaining the pre-development runoff peak flow, and the natural drainage patterns.
- Maintains temperature norms of storm water because they promote infiltration, evaporation and transpiration.

A19.2 Appropriate Applications

Dispersion should be considered where:

- Total Maximum Daily Loads have been established for surface waters within the project limits.
- Runoff would otherwise discharge to surface waters where there are threatened or endangered fish, or designated critical habitat.
- The project is within the boundaries of a designated Small Municipal Separate Storm Sewer System (Small MS4), or has storm water quality limits set by local government ordinance.
- Runoff would discharge to surface waters that have outstanding fishery resource values and support fish and fish habitat that are sensitive to increased water temperatures, sedimentation, suspended solids or turbidity.

Selected sites should be relatively level to gently sloping, or designed and constructed to be relatively level to gently sloping. The goal is to have the flows dispersed into the surrounding landscape such that there is a low probability that any surface runoff will reach a flowing body of water. Dispersion can be used for impervious or pervious surfaces that are graded to drain via sheet flow or are graded to collect and convey storm water to dispersion areas after going through a flow spreading or energy dissipater device. Natural dispersion sites should have dense existing vegetation with soil-binding roots.

A19.3 Limitations

- The effectiveness of dispersion relies on maintaining sheet flow to the dispersion area, which maximizes soil and vegetation contact and prevents short circuiting due to channelized flow. If sheet flow cannot be maintained, dispersion will not be effective.
- Where runoff is channelized upstream of the dispersion area, the channelized flow must be re-dispersed before entering the dispersion area. Energy dissipaters in conjunction with flow-spreading BMPs may be needed to prevent high velocities through the dispersion areas.
- MDT may ultimately have to purchase a right-of-way or easement to protect the dispersion area from future development, but this should be the last option a designer would choose.
- Dispersion areas may cost as much as other BMPs (ponds or vaults) because a right-of-way or easement may need to be purchased. For engineered dispersion, compost-amended soils may need to be added.
- When selecting dispersion areas, the designer should determine if there are groundwater management plans for the area, and contact the local or municipal water suppliers to determine if the project lies within a wellhead or groundwater protection zone, septic drainfield, or aquifer recharge area. These areas typically restrict storm water infiltration; however, the local jurisdiction may waive this requirement.

A19.4 Design Considerations

- The use of natural and engineered dispersion concepts within the same discharge area is acceptable.
- The required size of the dispersion area depends on the area contributing flow and the predicted rates of water loss through the dispersion system. The designer should ensure that the dispersion area is able to dispose of (through infiltration, evaporation, transpiration, and soil absorption) storm water flows predicted by an approved continuous runoff model.
- Natural dispersion areas should have dense vegetation with soil-binding roots.
- The average longitudinal (perpendicular to flow path) and lateral (parallel to flow path) slope of the dispersion area should not exceed 6:1.
- There should be no discernible flow paths through the dispersion area.
- There should be no surface water discharge from the dispersion area to a conveyance system or Category I or II wetland. If this is unavoidable then the PESC should more likely be designed as a vegetated filter strip.
- Dispersion areas should have infiltrative soil properties that are verified by the Materials Laboratory or a geotechnical engineer.
- Dispersion areas that have impervious areas (for example, abandoned roads with compacted subgrades) within them should have those areas tilled and reverted using soil amendments.
- Dispersion areas that are within a landslide hazard area must be evaluated by a geotechnical engineer or qualified geologist.
- Dispersion areas should have a separation of at least 3 ft (1 m) between the existing ground elevation and the average annual maximum groundwater elevation.

Design criteria on all Type A and some Type B soils (depending on saturated hydraulic conductivity rates) [soil types refer to USDA/NRCS Hydrologic Soil Groups]:

- For saturated hydraulic conductivity rates of 4 inches (100 mm) per hour or greater, and for the first 20 ft (6 m) (along the sheet flow path) of impervious surface that drains to the dispersion area, there must be 10 ft (3 m) of dispersion area width. For each additional 1 ft (300 mm) of impervious surface (along the sheet flow path) that drains to the dispersion area, 0.25 ft (76 mm) of dispersion area width is needed (measured in the direction of the flow path).
- For dispersion areas that receive sheet flow only from disturbed pervious areas (such as bare soil and non-native landscaping), for every 6 ft (2 m) (along the sheet flow path) of disturbed pervious area, 1 ft (300 mm) of dispersion area width is needed (measured in the direction of the flow path).

Design criteria on all Type C and D soils and some Type B soils (depending on saturated hydraulic conductivity rates) [soil types refer to USDA/NRCS Hydrologic Soil Groups]:

- For every 1 ft (300 mm) of contributing pavement width, 6.5 ft (2 m) of dispersion area width is needed (measured in the direction of the flow path).
- The dispersion area should have a minimum width of 100 ft (30 m) (measured in the direction of the flow path).

19.4.1 Additional Design Criteria Where Discharge to the Dispersion Area is Sheet Flow

- The sheet flow path leading to the dispersion area should not be longer than 75 ft (23 m) for impervious surfaces and 150 ft (45 m) for pervious surfaces. The sheet flow path is measured in the direction of flow and generally represents the width of the pavement area.
- The longitudinal length of the dispersion area should be equivalent to the longitudinal length of the roadway that is contributing sheet flow.
- Roadway side slopes leading to dispersion areas should be 4H:1V or flatter. Slopes steeper than 4:1 are allowed if the existing side slopes will not be disturbed and they are well vegetated and show no signs of erosion problems. Roadway side slopes that are 4:1 - 6:1 should not be considered part of the dispersion area.
- The longitudinal slope of the contributing area (perpendicular to the direction of sheet flow) should be less than 5%.
- Pervious shoulders and side slopes are not counted in determining the sheet flow path.

19.4.2 Additional Design Criteria Where Flow Spreaders or Dispersion Trenches are Needed to Create a Sheet Flow Discharge into the Dispersion Area

- Concentrated runoff from the roadway and adjacent upstream areas (for example, in a ditch or cutslope) must be incrementally discharged from the conveyance system (ditch, gutter, or storm sewer) via cross culverts or at the ends of cut sections. These incremental discharges of newly concentrated flows must not exceed 0.5 cfs at any single discharge point from the conveyance system for the 100-year runoff event. Where flows at a particular discharge point are already concentrated under existing site conditions (for example, in a natural channel that crosses the roadway alignment), the 0.5-cfs limit would be in addition to the existing concentrated peak flows.
- Discharge points with up to 0.2 cfs discharge for the peak 100-year flow may use rock pads or dispersion trenches to disperse flows. Discharge points with between 0.2 and 0.5 cfs discharge for the 100-year peak flow must use only dispersion trenches to disperse flows.
- Dispersion trenches must be designed to accept surface flows (free discharge) from a pipe, culvert, or ditch end; aligned perpendicular to the flow path; a minimum of 2 ft (600 mm) by 2 ft (600 mm) in section; 50 ft (15 m) in length; filled with ¾ - 1½ inch (19-38 mm) washed rock; and provided with a level notched grade board. Manifolds may be used to split flows up to 2 cfs discharge for the 100-year peak flow between four trenches (maximum). Dispersion trenches must have a minimum spacing of 50 ft (15 m).

- Discharge points must be located a minimum of 100 ft (30 m) up-gradient of steep slopes [slopes steeper than 40% within a vertical elevation change of at least 10 ft (3 m)], wetlands, and streams.
- Where the local jurisdiction determines that there is a potential for adverse impacts downstream (for example, erosive steep slopes or existing downstream drainage problems), dispersion of roadway runoff may not be allowed, or other measures may be required.

19.4.3 Pipe or Ditch Conveyance System

Flows collected in a pipe or ditch conveyance system require energy dissipation and dispersal at the end of the conveyance system before entering the dispersion area. For flow dispersal BMPs (for example, gravel-filled trenches, level spreaders) and techniques, see Section 20.0 Flow Spreading Options.

19.4.4 Setback Requirements

- Dispersion areas can extend beyond MDT right-of-way, provided that documentation on right-of-way plans ensures (via easement or agreement) that the dispersion area is not developed in the future.
- Dispersion areas should be set back at least 100 ft (30 m) from drinking water wells, septic tanks or drainfields, and springs used for public drinking water supplies. Engineered dispersion areas up-gradient of drinking water supplies must comply with DEQ requirements.
- The designer should check with the local land use agency for additional setback requirements.
- If the project measurably increases flows to off-site properties, a drainage easement may be required or right-of-way purchased.

A19.5 Materials

Consult the MDT Reclamation Specialist for specific seeding/planting guidelines. Materials for engineered dispersion will vary with the type of dispersion method used; refer to details (following this section) for specific items.

A19.6 Construction Considerations

- For installation of dispersal BMPs and conveyance systems near dispersion areas, the area that needs to be cleared or grubbed should be minimized. Maintaining plant root systems is important for dispersion areas.
- The area around dispersion areas should not be compacted.
- To the maximum extent practicable, low-ground-pressure vehicles and equipment should be used during construction.

A19.7 Operation and Maintenance

Maintenance of natural and landscaped areas designated as storm water treatment facilities requires special attention. Maintenance of these areas may include removing sediment, grading, and re-seeding. Generally, maintenance in these areas should be performed with light equipment. Heavy machinery and vehicles with large treads or tires can compact the ground surface, decreasing the effectiveness of the BMPs.

A19.8 Initial Cost and Cost Per Year

Natural Dispersion:

Initial Cost:	Low
Cost per Year:	Low

Engineered Dispersion:

Initial Cost:	Moderate
Cost per Year:	Low

A19.9 Method of Payment

The resources needed to adequately disperse flow will be paid as a lump sum.

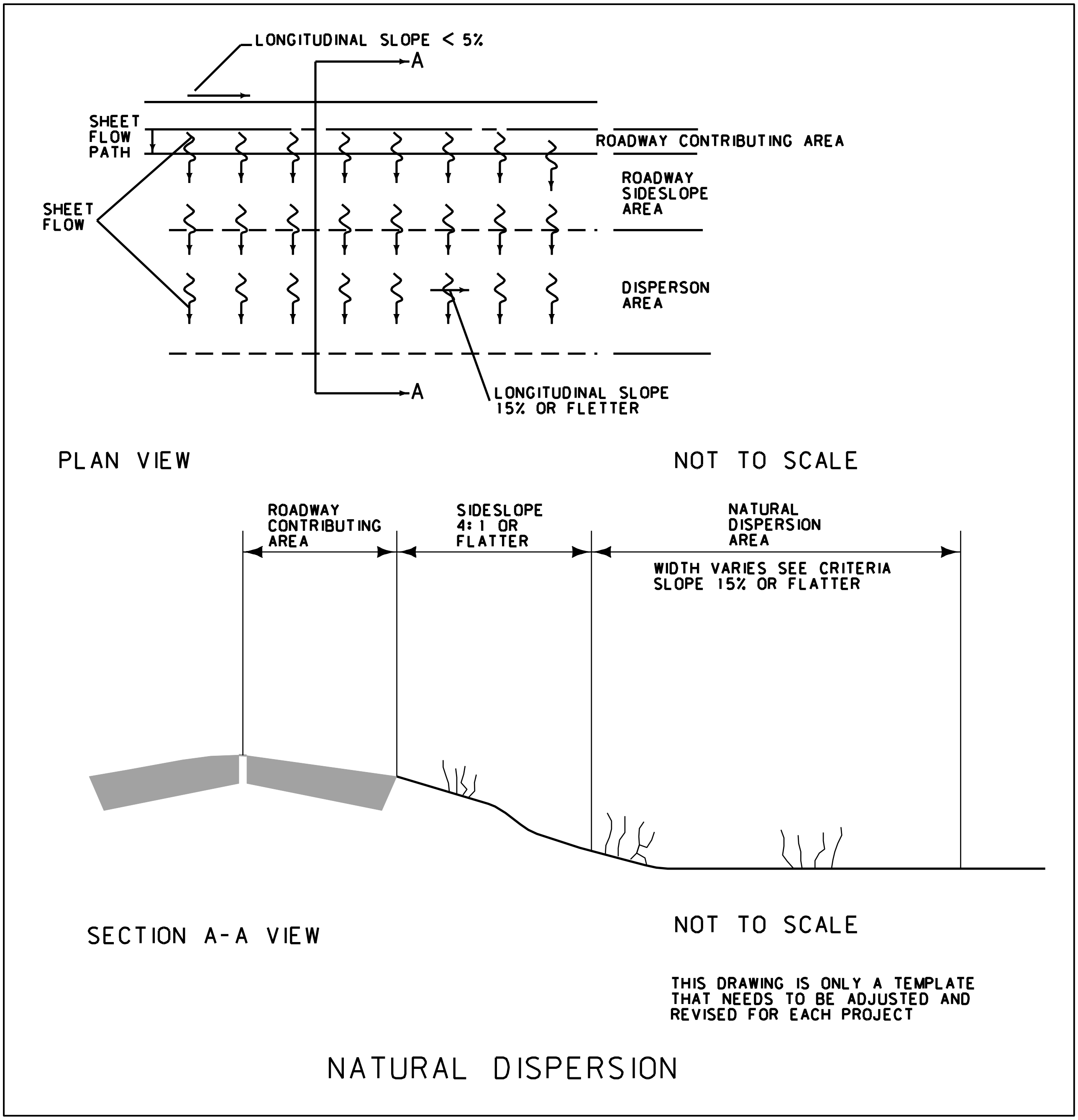


Figure A19-1: Natural Dispersion

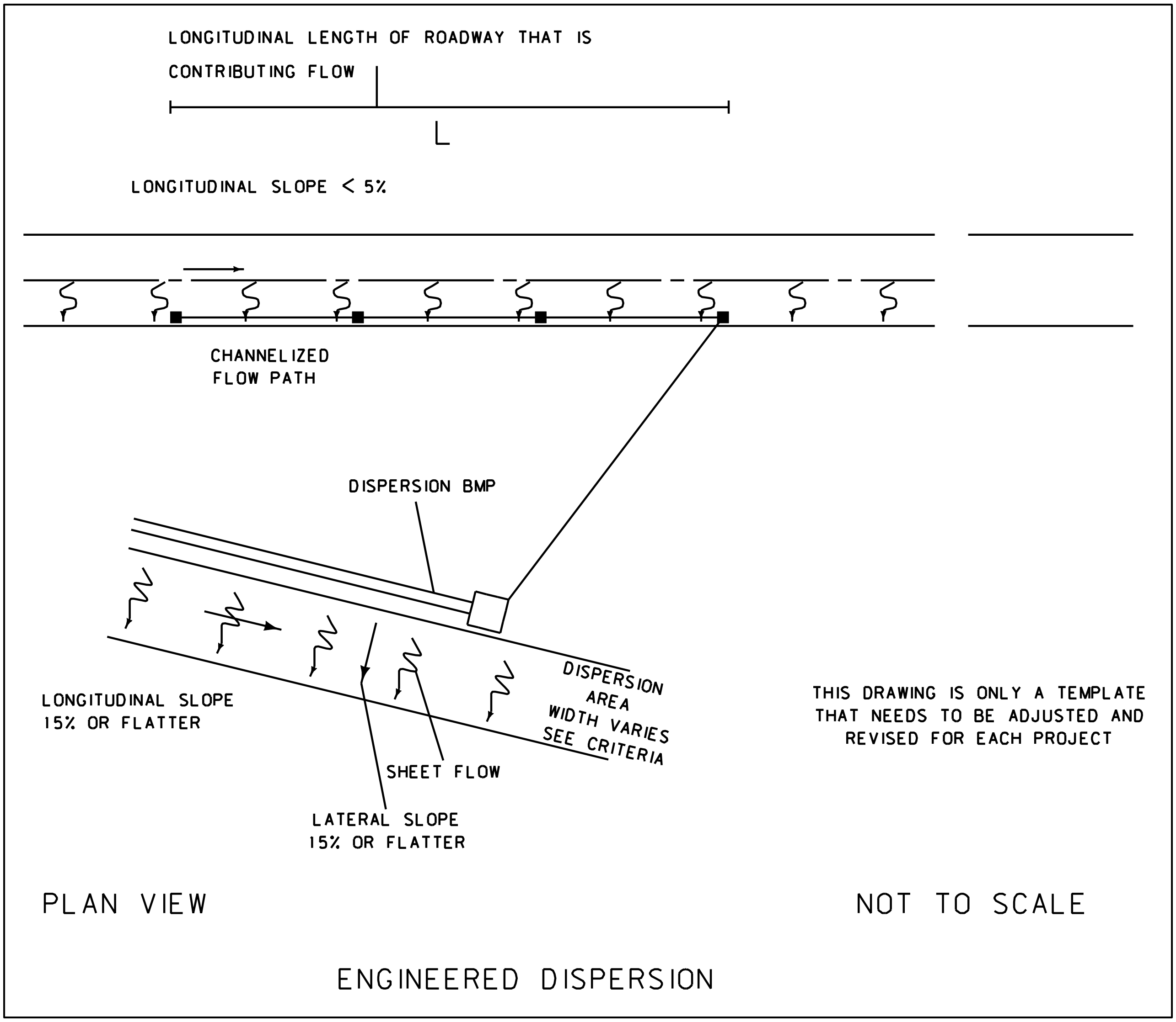


Figure A19-2: Engineered Dispersion

Runoff from a concentrated storm water conveyance system is diverted through a flow spreader to the engineered dispersion area. For an example of an engineered dispersion area receiving just sheet flow, please refer to Figure A19-2. An engineered dispersion area is designed and constructed (excavated or filled, graded, topsoiled, seeded and mulched, etc.) while a natural dispersion area is used as it already exists.

A20.0: FLOW SPREADING OPTIONS

A20.1 Definition and Purpose

Flow spreaders function to uniformly spread flows across the inflow portion or width of storm water treatment facilities or other PESC BMP (for example, biofiltration swale, vegetated filter strip, natural or engineered dispersion, constructed wetland, infiltration or settling basin). Seven flow spreader options are presented in this section:

- Option A – Anchored plate
- Option B – Concrete sump box
- Option C – Notched curb spreader
- Option D – Through-curb ports
- Option E – Interrupted curb
- Option F1 – Flow dispersal trench with perforated pipe
- Option F2 – Flow dispersal trench without perforated pipe

A20.2 Appropriate Applications

Options A through C can be used for spreading flows that are concentrated. Any one of these options can be used when spreading is required by the facility design criteria.

Options A through C can also be used for un-concentrated flows and in some cases they must be used, such as to correct for moderate grade changes along a vegetated filter strip.

Options D and E are only for flows that are already un-concentrated and enter a vegetated filter strip or continuous inflow biofiltration swale. Other flow spreader options are permitted with approval from MDT Hydraulics.

Options F1 and F2 can be used when an outfall is needed to spread concentrated flows across uplands where no conveyance system exists and the existing (pre-disturbance) discharge is not concentrated. They can also be used to distribute or spread concentrated flows across the inflow portion or width of storm water treatment facilities or other PESC BMP.

A20.3 Limitations

Flow spreading options can only be used where the existing terrain is conducive to spreading flows. It is impractical to grade an area to effectively disperse flows.

A20.4 Design Considerations

Contact and coordinate with MDT Hydraulics for proper sizing of culverts, pipes, sump boxes or other hydraulic structures and features.

Where flow enters the flow spreader through a pipe, it is recommended that the pipe be submerged to the extent practical to dissipate energy as much as possible.

Options A through D - For higher inflows [greater than 5 cubic ft/sec (1.5 cms) for the 100-year storm], a catch basin should be positioned in the spreader, and the inflow pipe should enter the catch basin with flows exiting through the top grate. The top of the grate should be lower than the level spreader plate or, if a notched spreader is used, lower than the bottom of the V-notches.

A20.4.1 Option A – Anchored Plate

- An anchored plate flow spreader (see Figure A20-1) must be preceded by a sump having a minimum depth of 8 inches (200 mm) and a minimum width of 24 inches (600 mm). If not otherwise stabilized, the sump area must be lined to reduce erosion and to dissipate energy.
- The top surface of the flow spreader plate must be level, projecting a minimum of 2 inches (50 mm) above the ground surface of the runoff treatment facility, or V-notched with notches 6-10 inches (150-250 mm) on center and 1-6 inches (25-150 mm) deep (use shallower notches with closer spacing). Alternative designs may also be used.
- A flow spreader plate must extend horizontally beyond the bottom width of the facility to prevent water from eroding the side slope. The horizontal extent should protect the bank for all flows up to the 100-year flow or the maximum flow that enters the runoff treatment facility.
- Flow spreader plates must be securely fixed in place.

A20.4.2 Option B – Concrete Sump Box

- The wall of the downstream side of a rectangular concrete sump box (see Figure A20-2) must extend a minimum of 2 inches (50 mm) above the treatment bed. This serves as a weir to spread the flows uniformly across the bed.
- The downstream wall of a sump box must have wing walls at both ends.
- Sidewalls and returns must be slightly higher than the weir so that erosion of the side slope is minimized.
- Sump boxes must be placed over bases consisting of 4 inches (100 mm) of crushed rock, 5/8-inch (16 mm) minus, to help ensure that the sump remains level.

A20.4.3 Option C – Notched Curb Spreader

Notched curb spreader sections (see Figure A20-3) must be made of extruded concrete laid side-by-side and level. Typically 5 teeth per 4-foot section provide good spacing. The space between adjacent teeth forms a V-notch.

A20.4.4 Option D – Through-Curb Ports

Un-concentrated flows from paved areas entering vegetated filter strips or continuous inflow biofiltration swales can use curb ports (see Figure A20-4) or interrupted curbs (Option E) to allow flows to enter the strip or swale. Curb ports use fabricated openings that allow concrete curbing to be poured or extruded, with an opening through the base to admit water to the runoff treatment facility.

Openings in the curb must be at regular intervals, at least every 6 ft (2 m) minimum. The width of each curb port opening must be a minimum of 11 inches (279 mm). Approximately 15% or more of the curb section length should be in open ports, and no port should discharge more than about 10% of the flow.

A20.4.5 Option E – Interrupted Curb

- Interrupted curbs are sections of curb with gaps spaced at regular intervals along the total width (or length, depending on facility) of the treatment area.
- At a minimum, gaps must be every 6 ft (2 m) to allow distribution of flows into the treatment facility before the flows become too concentrated.
- The opening must be a minimum of 11 inches (279 mm). As a general rule, no opening should discharge more than 10% of the overall flow entering the facility.

A20.4.6 Options F1 and F2 – Flow Dispersal Trenches

The flow dispersal trenches shown in Figures A20-5 and A20-6 can be used when:

- The 100-year peak discharge rate is less than or equal to 0.5 cubic ft per second (0.015 cms).
- An outfall is necessary to disperse concentrated flows across uplands where no conveyance system exists and the natural (existing) discharge is un-concentrated.
- It is needed to distribute or spread concentrated flows across the inflow portion or width of storm water treatment facilities or other PESC BMP.

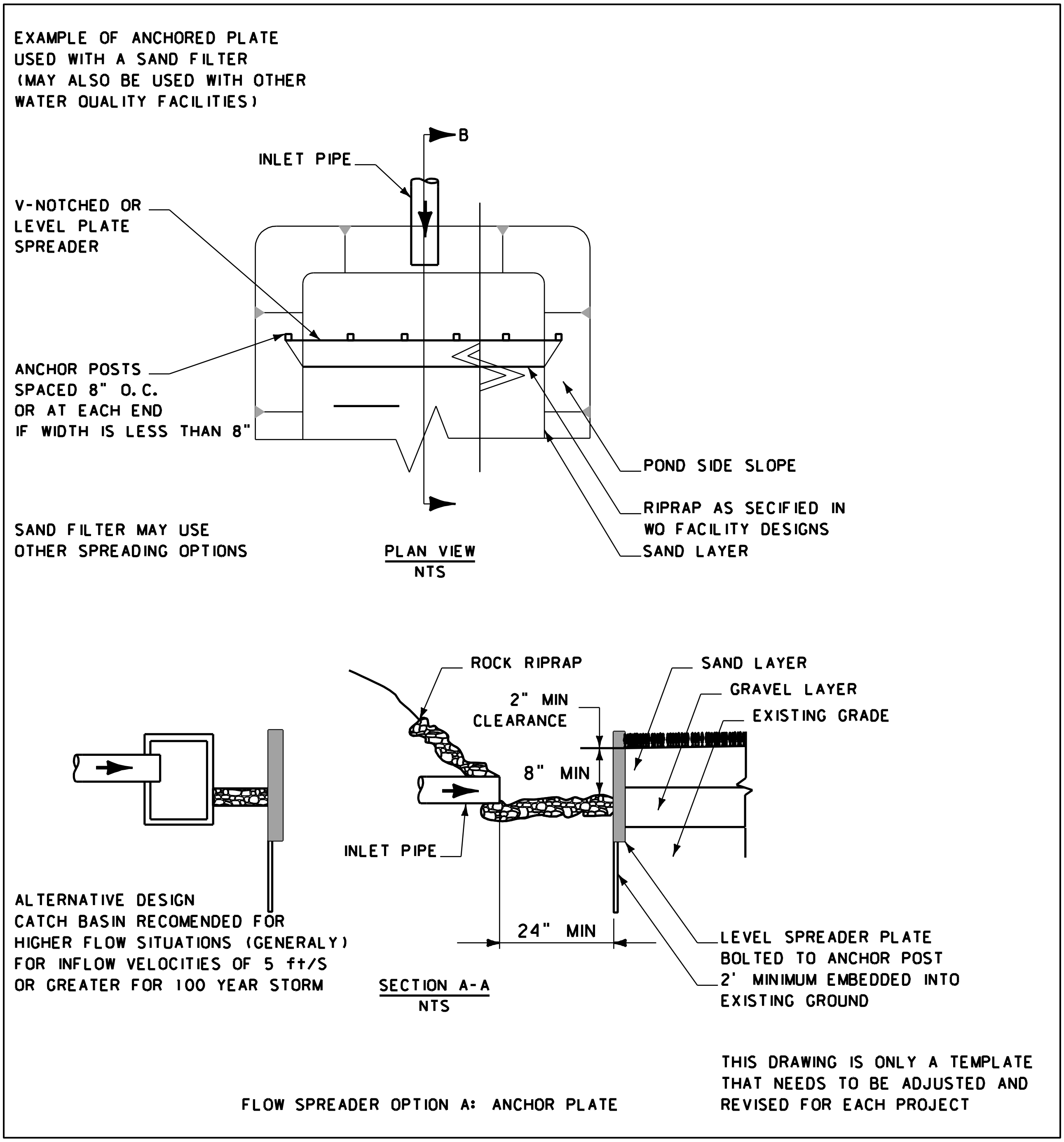


Figure A20-1: Option A – Anchor Plate

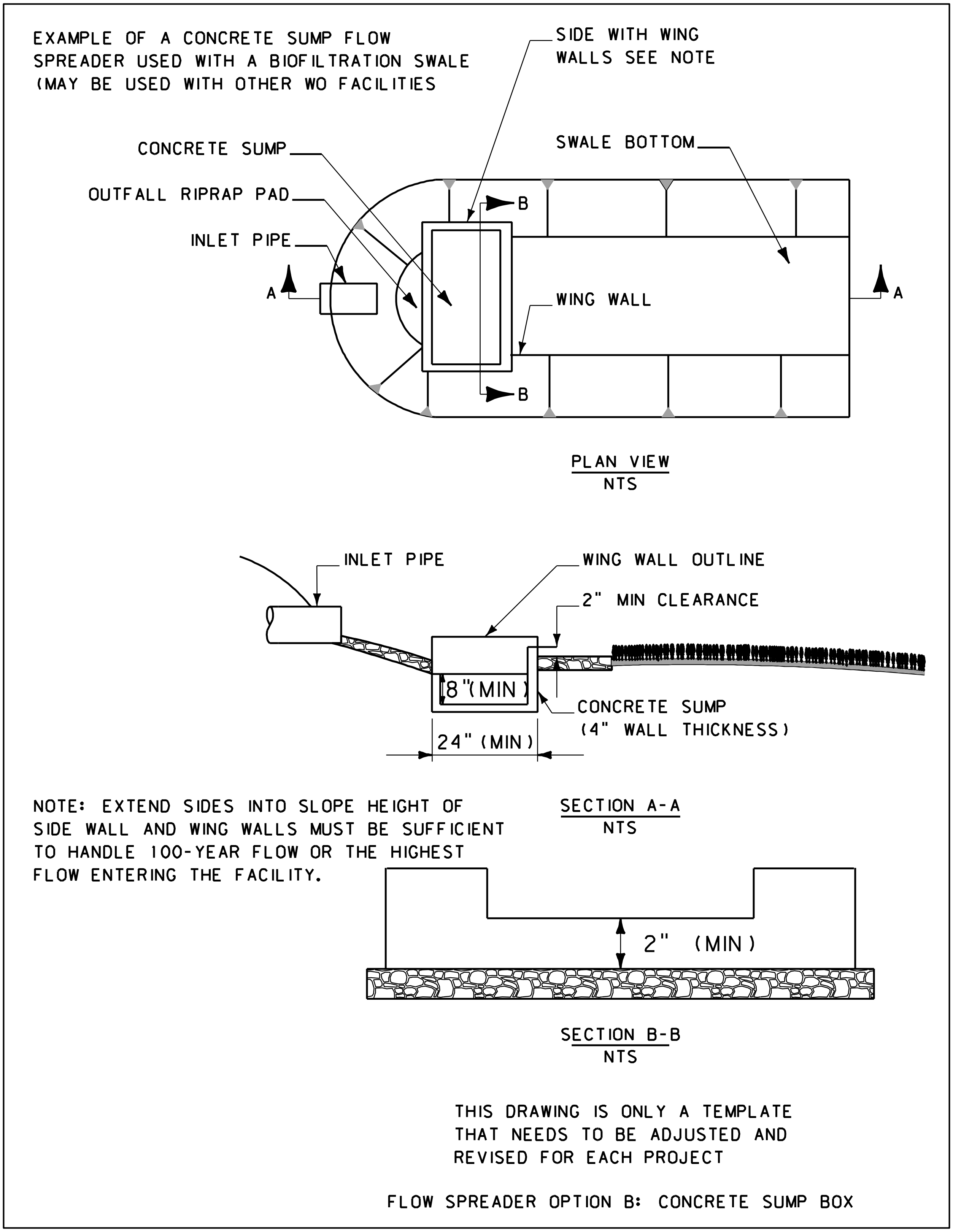


Figure A20-2: Option B – Concrete Sump Box

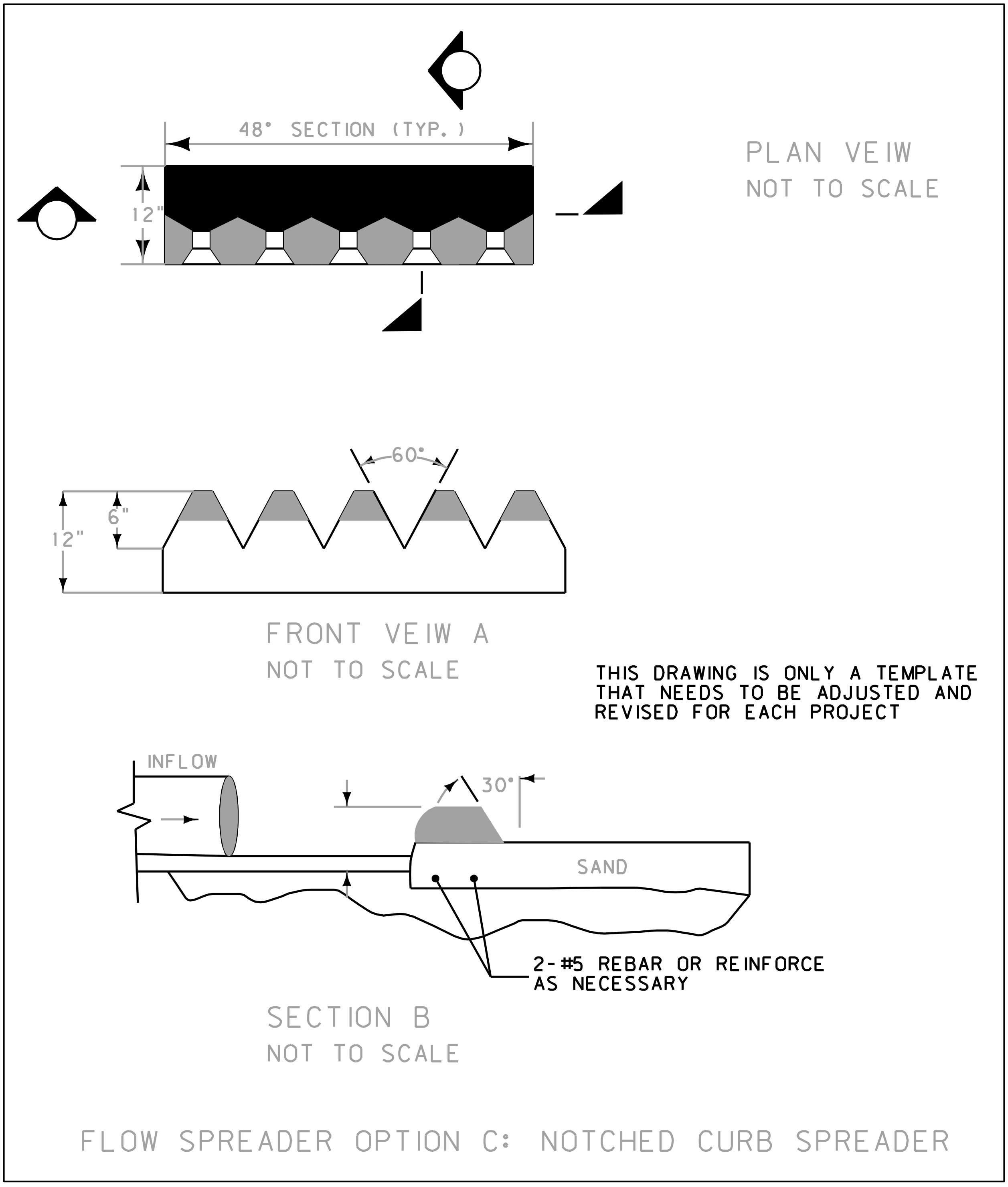


Figure A20-3: Option C – Notched Curb Spreader

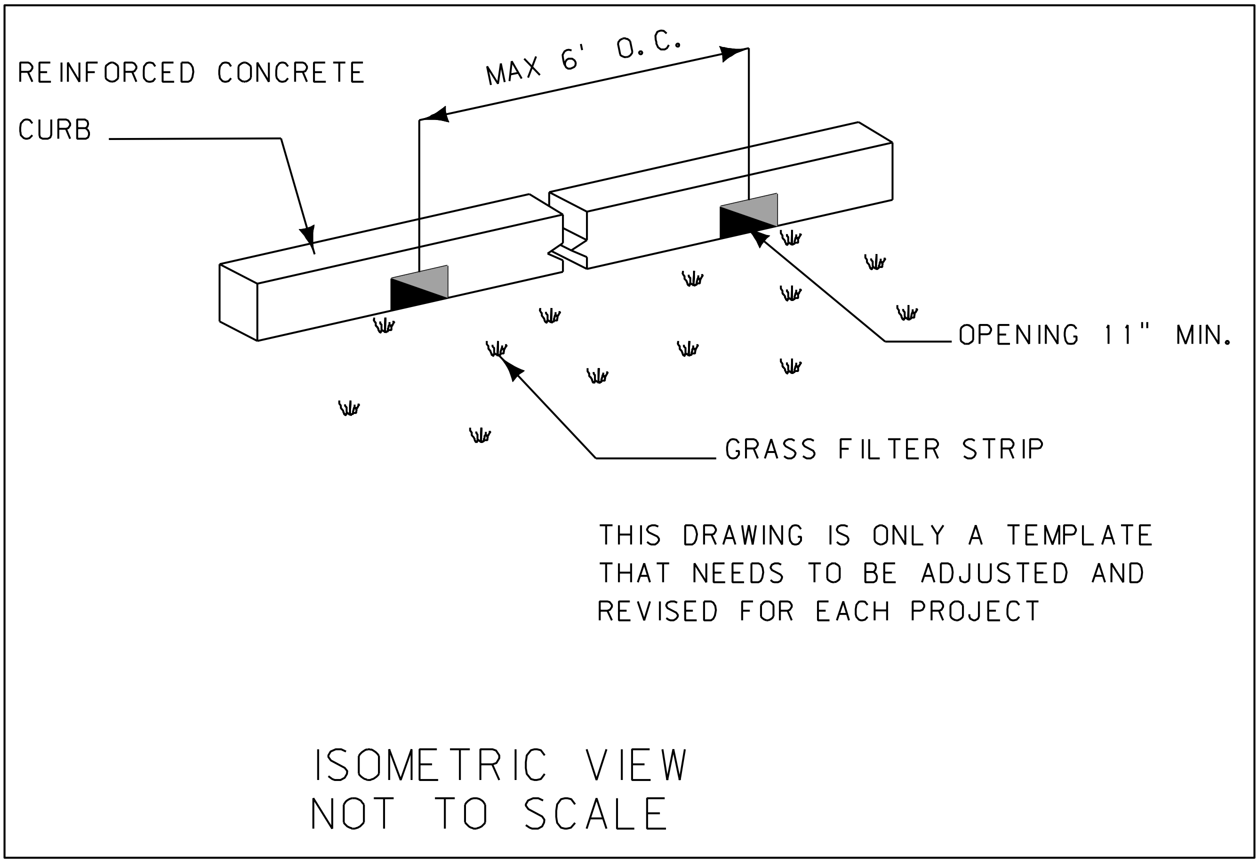


Figure A20-4: Option D – Through-Curb Port

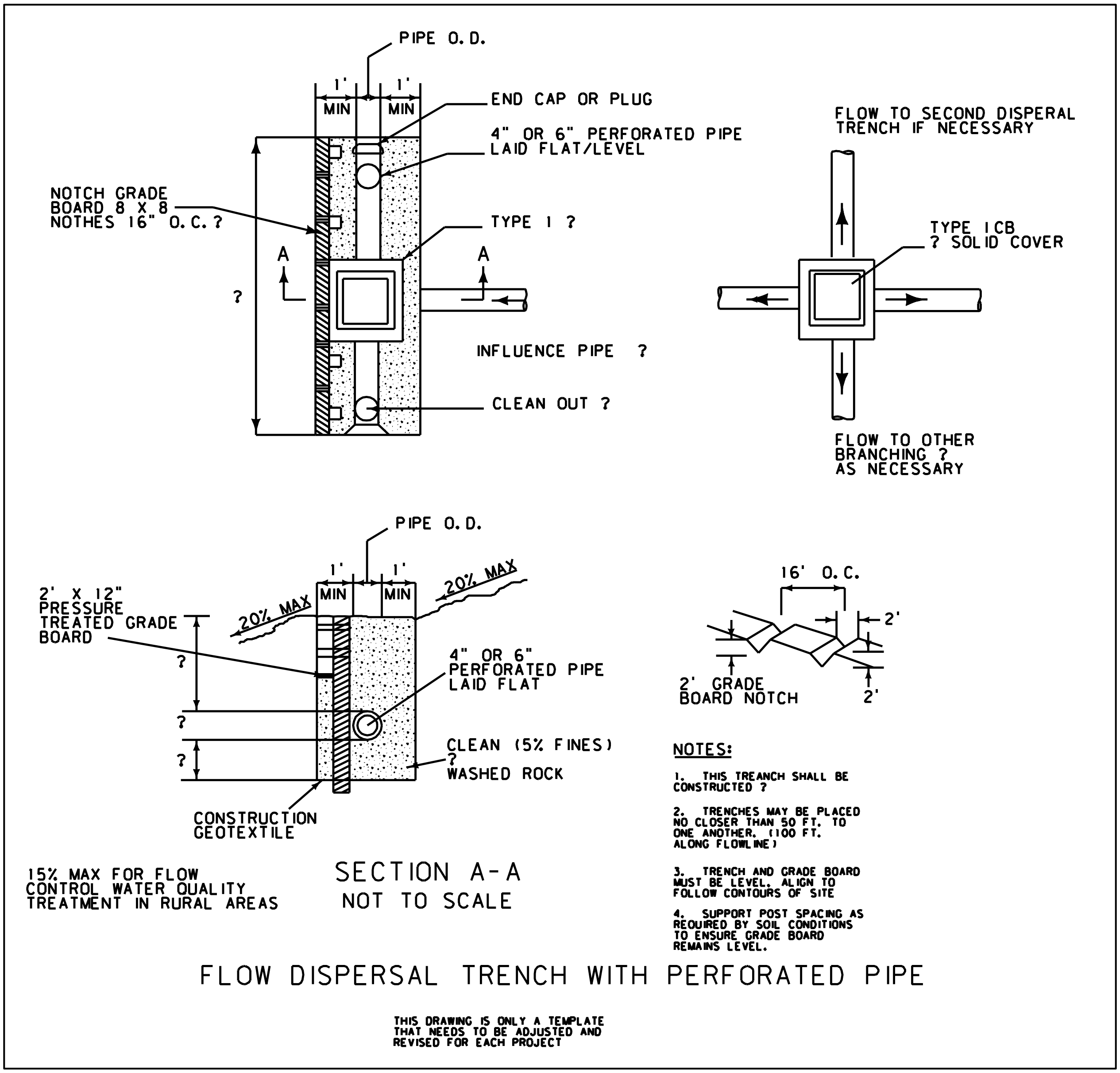


Figure A20-5: Option F1 – Flow Dispersal Trench With Perforated Pipe

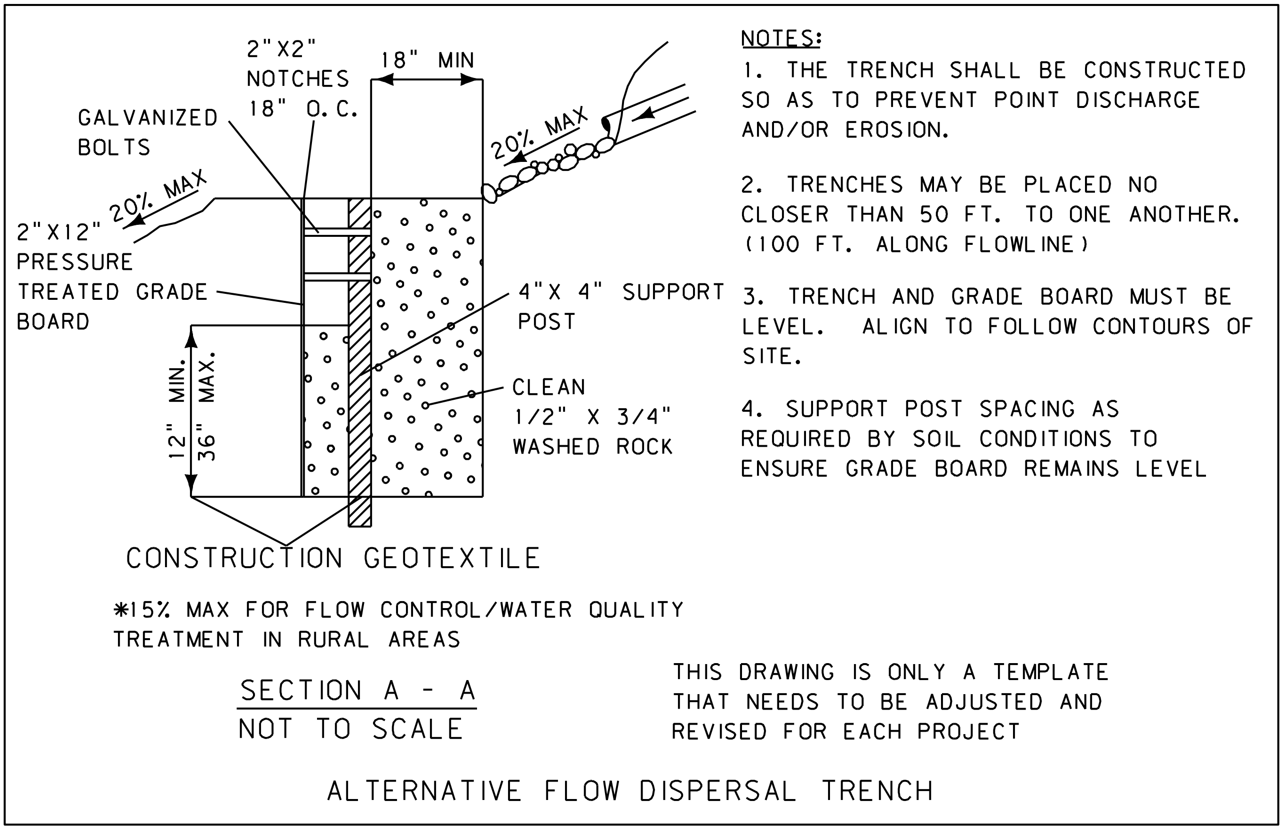


Figure A20-6: Option F2 – Flow Dispersal Trench Without Perforated Pipe

A20.5 Materials

A20.5.1 Option A – Anchored Plate

- Flow spreader plates may be made of either wood, metal, fiberglass-reinforced plastic, or other durable material. If wood, pressure-treated 4-inch by 10-inch (100 by 250 mm) lumber/landscape timbers are acceptable.
- Anchor posts must be 4-inch-square (100 mm square) concrete, tubular stainless steel, or other material resistant to decay.

A20.5.2 Option B – Concrete Sump Box

Concrete for a sump box can be either cast-in-place or precast, but the bottom of the sump must be reinforced with wire mesh for cast-in-place sumps.

A20.6 Construction Considerations

Refer to the specific flow spreading options measures in preceding subsections.

A20.7 Operation and Maintenance

Inspect flow spreading options annually to ensure that they are functioning properly.

A20.8 Initial Cost and Cost Per Year

Initial Cost:	Moderate
Cost per Year:	Low

A20.9 Method of Payment

Flow spreading options will be paid per each.